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THESIS

DESIGN OF AN EFFECTIVE VISUALIZATION FOR NAVAL CAREER INFORMATION SUMMARY AND EVALUATION

by

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September 2003

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13. ABSTRACT

By using visualization best practices and embedding them in information technology (IT), we believe that the Department of Defense can improve its ability to display multi-variant information. The focus of this research is to design a visual information solution, based on best practices for displaying performance data visually, to the Electronic Military Personnel Record System (EMPRS). Ultimately, our goal is to improve the overall effectiveness and objectivity of the Navy's selection board processes by providing a re-engineered, web–based, graphical solution to the visual displays currently in use by selection boards. The current Navy selection board voting process uses tabular forms displayed across five screens in a small theater-like setting. The forms are displayed very quickly allowing board members very little time to mentally assimilate the quantitative data dispersed over a wide area. In our model, we distill the data into a single graphical display, thus reducing the cognitive computing requirements of the board members. We used the Knowledge Value Added methodology to determine the proposal's relative effectiveness and developed a prototype as a proof of concept. With this study and follow on recommendations, we foresee a considerable improvement potential in the Navy's promotion board procedures and outcomes.

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DESIGN OF AN EFFECTIVE VISUALIZATION FOR NAVAL CAREER INFORMATION SUMMARY AND EVALUATION

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By using visualization best practices and embedding them in information technology (IT), we believe that the Department of Defense can improve its ability to display multi-variant information.

The focus of this research is to design a visual information solution, based on best practices for displaying performance data visually, to the Electronic Military Personnel Record System (EMPRS). Ultimately, our goal is to improve the overall effectiveness and objectivity of the Navy's selection board processes by providing a re-engineered, web–based, graphical solution to the visual displays currently in use by selection boards.

The current Navy selection board voting process uses tabular forms displayed across five screens in a small theater-like setting. The forms are displayed very quickly allowing board members very little time to mentally assimilate the quantitative data dispersed over a wide area. In our model, we distill the data into a single graphical display, thus reducing the cognitive computing requirements of the board members.

We used the Knowledge Value Added methodology to determine the proposal's relative effectiveness and developed a prototype as a proof of concept. With this study and follow on recommendations, we foresee a considerable improvement potential in the Navy's promotion board procedures and outcomes.

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TABLE OF CONTENTS

LIST OF FIGURES

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LIST OF TABLES

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Major Glenn A. Rogers

I would like to thank my wife Mechelle, and two wonderful daughters, Hanna and Katelyn, for their patience, understanding, and encouragement throughout the process of working on this project.

Captain Jason D. Grose, USMC

This thesis is the culmination of gifts from every teacher thus far in my life. I want to thank Mr. Brian Maxwell, my 10th grade math teacher, for sparking my interest in math and scholastics in general. To the Marine Corps who taught me how to be a man and specifically Drill Instructor Sergeant Major Jon Wertjes who taught me how to be a Marine. To my mentor, Sergeant Shane Maxey, who taught me how to be an NCO and father, and to Major Philipp Patch who taught me how to be an Officer. And to my best teachers of them all: my kids, Alex and Stephanie, who taught me how to enjoy life through kids' eyes again and my wife, Carrie, for teaching me what's really important in life. I thank you all for investing.

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EXECUTIVE SUMMARY

A critical issue in an officer's career is the opportunity for promotion. In today's technology information rich environment, it is important to re-evaluate and possibly change the way promotion information is presented to a selection board. The current method of displaying a candidate's personnel record for promotion or selection relies heavily on human cognition to process tabular, quantitative information in the form of the Officer Summary Record (OSR) and the Performance Summary Record (PSR) information. Board members use the OSR/PSR information to gain insight into the candidate's personnel data, promotion history, educational background, and job performance in specific billets to evaluate each candidate for promotion potential. The current data-to-information conversion process relies entirely on notes, symbols, and highlighted annotations on the digital summary record forms to convey the candidate's potential for promotion to the other board members. During the promotion process, this quantitative information is displayed across three to five screens in a small theater-like setting. The forms are displayed for two to three minutes as the individual's record is reviewed by the board members. This restricted form of information presentation makes it difficult to compare candidates and may even lead to distortions in the evaluation process.

We consider it essential that the board members can quickly review and understand the information presented on the summary forms; information currently extracted from several legacy data systems using outdated information retrieval processes. We see a short-lived opportunity as the Navy plans to move toward a single source human resource system and concurrently redesigns the Electronic Military Personnel Record System (EMPRS). Now is an appropriate time to review the adequacy of the tools used to present career information and if is the system developers determine that there is a more useful career information summary tool for selection board members, the tool needs to be identified early in the development of future information systems and integrated into the proposed designs.

One of the greatest benefits of data visualization is the sheer quantity of information that can be rapidly interpreted if presented well (Ware, 2000). This thesis will offer examples of how to best transform the data into information that the board members can use for optimal decision making. Our goal is to provide a re-engineered, web–based, graphical solution to the visual displays currently used by selection boards. The improved format will display an individual's career data by graphically displaying an officer's career data in a method that maximizes information flow to the briefer and selection board while minimizing selection board member training, record preparation time, and mental "data to information" processing time in the promotion evaluation process.

This study includes an in depth literature review of the most current visualization techniques for multi-criteria decision-making models in conjunction with well established principles for the display of visual information. Much of this theory is based off of Edward Tufte's classical works on the visualization of data.

The Knowledge Value Added (KVA) methodology is used in order to measure the relative effectiveness of the proposal against the current system. KVA is a framework for measuring the value of organizations knowledge assets and provides a methodology for allocating revenue and cost to an organization's core processes, based on the amount of change each produces. KVA standardizes the output of all processes by describing the output in terms of the units of knowledge required to produce it. KVA uses a Return on Knowledge (ROK) ratio of the current system compared to the proposed system in order to compare the measurement of the knowledge value embedded in the organization's core processes.

Our main research question asks whether data-information visualization best practices can be embedded in information technology in order to improve the overall effectiveness and objectiveness of the selection board process. We introduce a proof-of-concept (POC) prototype visualization solution through the use of Commercial Off The Shelf (COTS) software and technology in order to demonstrate the visualization concepts and capabilities currently available.

The KVA analysis we calculated in this study proves that by using a web-enabled system and graphically displaying the information, the process becomes more efficient by saving time and money during each board session. For the next phase of future evaluation, we recommend that a side-by-side analysis using a beta system be used in conjunction with the old system in an actual board. By surveying the board members immediately after the board session, researchers could harvest immediate insights whether or not the new graphical displays assist in perceiving and correlating the quantitative information. Our study suggests that by surveying multiple boards and making the recommended improvements, future researchers could acquire empirical feedback necessary to determine whether or not the proposed system contributes or detracts from increasing the effectiveness and objectiveness of the overall process. This thesis also suggests that by reducing the preparation, briefing, and voting times for the board members, some of the emotional and physical strain internal to multiple decision-making within a confined time period would also be reduced. This improvement may well translate to more effective, and ultimately more objective decisions.

In summary, this thesis' primary practical focus is to make recommendations that will enhance the board members' comprehension of the data which in turn, renders the current process more effective, efficient, and objective. The recommendations set forth in this study are important concepts that may contribute to immediate, short-term results such as shortening the selection board process while increasing its efficiency. A significant, long term effect includes a potential increase in retention rates resulting from a perceived improvement and effectiveness in the promotion or assignment systems.

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I. INTRODUCTION

A. PURPOSE

With the advancement of technology and in particular the rapid progression of the Internet, decision makers face an increasing problem of having too much raw information available. Often this problem is further exacerbated by the fact that all of the data and multi-variant information is not displayed in the most effective manner. As the speed and complexity of information greatly increases, the demand for visual tools to make sense of that information will only grow. By using visualization best practices and embedding them in information technology (IT), we believe that the Department of Defense can improve its ability to display multi-variant information. This thesis's goal is to determine the best way to communicate more information per unit of time. In other words, what is the best way to transform data into information that can be quickly and accurately communicated effectively to others?

The focus of this research is to design a visual information solution, based on best practices for displaying performance data visually, to the Electronic Military Personnel Record System (EMPRS) to improve the overall effectiveness and objectivity of the Navy's selection board processes. The goal is to provide a re-engineered, web–based, graphical solution to the visual displays currently in use by selection boards, in an improved manner and format that will display an individual's career data. By maximizing information flow to the briefer and selection board and minimizing selection board member training, record preparation time, and labor-intensive "data to information" processing time in the promotion evaluation process, the ultimate re-design should be clear, concise, comprehensive, and entail a scalable methodology allowing for changing performance dimensions. An additional objective is to propose the Knowledge Value Added (KVA) methodology as a metric by which to gauge or measure this solution against the current process in order to determine its relative future effectiveness.

1. Scope

This thesis is primarily concerned with the graphical representation of information to maximize information flow about an individual's promotion/selection potential while minimizing the amount of effort the user expends extracting this information. Emphasis

is placed on the evaluation of the human factors involved in the effective display of visual information, to include size of display, colors used in the display, and effective ways to present information. The current form uses only text and grid lines. Included in this study is an evaluation of other ways to present information, such as with charts or graphs, to more effectively convey the information reviewed on the summary form.

The vision of this project as articulated by the Navy Personnel Command (NPC) is that of a two-phased implementation with the first phase being the incremental step of re-designing the visual displays to look at today's "Report Card" (OSR/PSR data). This is the phase that our thesis addresses. The second phase is a radical re-design of the displays to encompass "Tomorrow's Five Vector Model" in the advancement and future promotion of Naval personnel. The scope of the two phased implementation is as follows:

a. Naval Postgraduate School (NPS) Project Scope

The current displays are used by selection boards, detailers, and other career planners to determine the future promotion, advancement, and assignment of Navy personnel. In an attempt to limit the scope of this project, the authors have decided only to use the officer statutory selection board process example in which to base the study and proof of concept model. Our intent is that this system will evolve into a true web-based interactive model, however, at the present time this web-based format has yet to be identified, so we have chosen to develop a proof of concept model using Macromedia Dreamweaver MX for our web application, utilizing a three tier architecture encompassing a notional Microsoft Access relational database. Due to the limited time and resources available for this research, we have decided to expend minimal effort on explaining the complexities of the current network and data base architectural technologies that exist and that are currently being re-engineered through the Navy's personnel and manpower modernization effort.

b. Navy Personnel Command (NPC) Project Scope

The Navy Personnel Command's focus and scope states that the re-engineering effort must design a visual display with the following characteristics:

- Compatible with the Electronic Military Personnel Records Management System (EMPRS) or the technical refreshed version of EMPRS currently under development
- Compliant within the NMCI network standards and operate successfully within enclave
- Should have compatibility with PeopleSoft HRMS applications
- Operational within Wood Hall Bldg. 769, Navy Personnel Command (NAVPERSCOM)
- Will provide executable design for selection boards
- Will not alter current processes or require changes to U.S. Code title 10 promotion law, or career milestones
- Will not change manpower requirements for operations and support
- Increases the relative effectiveness of visual displays
- Provides for a graphical representation of OSR/ESR (Officer/Enlisted Summary Records) data reflecting performance history, awards, and promotion progression set against a career timeline or history of assignments.
- Integral into the project portfolio of Sea Warrior
- Successfully extracts data for the Five Vector Model (5VM) from the Navy Personnel Database (NPDB) and the Navy Standard Integrated Personnel System (NSIPS).

2. End State

The primary practical focus of this research is to make recommendations in order to enhance the promotion board members' comprehension of the data in a way that makes the current process more effective, efficient, and objective. This is an important factor that may contribute to immediate short-term results, such as shortening the selection board process while increasing its efficiency. Long term effects could include an increase in retention rates due to the enhancement of personnel satisfaction attributed to a more effective determination of the future promotion or assignment of Navy personnel. The overall vision is for a two-stage implementation with the final stage using the enhanced displays for the projection of the Five Vector Model for promotion purposes in the future.

The concept of the Five Vector Model is to show Naval personnel their career path, identify the requirements they need to complete, and to qualify them for future assignments. The model aligns professional development requirements with certifications and qualifications (military and civilian) that are recognized as the industry standard. Once the Fleet has identified the requirements, subject matter experts (SMEs) in each field plot them on the vector model where an individual should ideally meet those milestones in their career. The model also considers personal development, leadership,

management, and individual performance. (Ferron). The ultimate end state and radical re-design would then be to use the first phase re-design of the visual displays to show the Five Vector Model as a way of displaying the qualifications and individual performance with regard to promotion.

The immediate benefit of this study, however, will be an improved process for effectively and efficiently selecting and promoting Naval officers by improving the visual representation of performance information for the selection boards while minimizing selection board member training, reducing record preparation time, and reducing the mental "data to information" processing time.

B. BACKGROUND

The Performance Summary Record (PSR), Officer Summary Record (OSR) and Enlisted Summary Record (ESR) are used by selection boards, detailers, and other career planners to determine the future promotion, advancement and assignment of Navy personnel. During the selection board process, two or three different forms are displayed across three to five screens in a small theater-like setting referred to as the "tank." These forms are displayed for two to three minutes as the individual's record is reviewed by the board membership. It is essential that the board members quickly review and understand the information presented on the summary form. The summary forms are currently designed to capture a combination of basic personnel information including designator or rating, year group, education history, and special qualifications. The form also includes a listing of duty assignments and a numeric summary of performance marks that the individual under consideration has received throughout his or her career. These forms are annotated by selection board members and used to brief other selection board members on the individual's career. The personnel data displayed on the forms are predetermined and there is no ability to tailor the form or the information on the form for specific types of boards. When special career information is required for a particular type of board, that information must be manually entered on the form by selection board administrative staff. The information on the forms is extracted from several legacy data systems using outdated information retrieval processes.

1. Current Process

The current method of displaying a candidate's personnel record for promotion or selection decisions relies primarily on human cognition to process tabular O/ESR and PSR data into the required information used for comparison and decision-making. Board members use Officer/Enlisted (O/E) Summary Record Forms and Performance Summary Records to gain insight into the candidate's personnel data, promotion/advancement history, educational background, and job performance in specific billets in order to evaluate promotion or selection potential. Applicable portions of the candidate's record on microfiche are used to add more detail to the performance, award, education, and special qualifications entries made on the summary records. A system to provide the candidate's data, called the Electronic Military Personnel Records System, has been implemented and is explained in further detail in chapter II.

2. Need for Improvement

This current data-to-information conversion process relies entirely on notes, symbols, and highlighted annotations on the digital summary record forms to convey the candidate's potential to other board members for promotion or selection decisions in a short three minute or less presentation. The format in which to view this information currently is limited and burdensome because it is made up of primarily quantitative data dispersed widely across five different display screens, thus forcing board members to search for and extract relative pieces of data and then mentally process and integrate the data into useful information. This restricted form of information presentation makes it difficult to compare candidates at a minimum, and may conceivably even lead to distortions in the evaluation process.

C. RESEARCH QUESTIONS

This thesis will attempt to answer the principle research question of whether data-information visualization best practices can be embedded in information technology in order to improve the overall effectiveness and objectiveness of the selection board process. Additionally, will integrating web-based technology with the visualization techniques reduce the time required to prepare, brief, and make decisions in the promotion process? Can web-based data visualization technologies serve as an enabler to

this problem, and if so, what are the relevant criteria for deciding which technologies are the most appropriate in this regard? What is an appropriate user interface design for this decision problem?

In order to answer these questions, our research will explore subordinate and more specific questions such as which principles of graphical practice apply to this type of data and which will best convert the data into meaningful visual information in this decision context? Are there colors, layering/separation, or multidimensional schemes that would facilitate information flow without inserting bias in envisioning a candidate's personal and performance information? We will also introduce the Knowledge Value Added methodology which will provide us with a performance ratio for all the core processes involved in order to determine if there is any increase in effectiveness between the "as-is" and "to–be" models.

D. METHODOLOGY

1. Proof of Concept Context

The proof-of–concept context for this research is the current Naval officer promotion/selection process. In order to answer the principle research question, the authors have developed a proof-of-concept prototype visualization solution through the use of Commercial off the Shelf (COTS) software and technology in order to demonstrate the visualization concepts and capabilities currently available. This prototype uses an artificial database and simulates the current system's input and outputs. Using three-tier architecture, the prototype extracts the data from the database and presents an improved visual display for the board to interpret and compare. In order to achieve the research goals, we have completed the following analysis and prototype development:

- An "as-is" analysis with a Return on Knowledge (ROK) spreadsheet and graphical representation.
- A "to-be" incremental model spreadsheet.
- A fully functional web site that utilizes a notional relational database.
- Prototype web-based charts and graphs using different colors, along with layering and separation multidimensional schemes that would facilitate information flow.

2. Literature Research

In order to gain extensive insight into the most effective and objective methods of displaying quantitative information, the authors have conducted an in depth literature review of the most current visualization techniques for multi-criteria decision-making models in conjunction with well established principles for the display of visual information. Much of this theory is based off of Edward Tufte's classical works on the visualization of data.

Additionally we have conducted a detailed study of the Knowledge Value Added methodology and have primarily focused our area of research on works of KVA's foremost authority and co-originator, Dr. Thomas Housel.

E. ORGANIZATION OF THESIS

This thesis is organized into five major sections or chapters. Chapter I is the overview of our research. Chapter II is primarily devoted to explaining the promotion board process in detail. This chapter is mainly for the reader with little or no background in the Naval Promotion Board process. Chapter III reviews the theory and literature used in the research. Chapter IV clarifies the details of the Knowledge Value Added methodology used to compare the current and future system. Chapter V will introduce our working prototype. Finally, Chapter VI will follow up with a conclusion, some recommendations, and possible areas for further research.

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II. PROMOTION BOARD PROCESS

A. OVERVIEW

This chapter will help the reader to understand the promotion processes and procedures that are detailed in the remainder of this document, particularly the literature review in chapter III. It is particularly important for the reader to have a solid understanding of the process before we explain our proof of concept methodology in the later chapters. We briefly outline the promotion board process as it exists today and cover the basics of the process. With this chapter, we intend to inform the reader who has not had any prior experience with, or knowledge of, the Navy's promotion board process.

There are two types of boards: Statutory and Administrative. Statutory boards include promotion (including special and spot promotion boards), Selective Early Retirement Boards (SERB), and various continuation boards.

All other boards are administrative. Statutory boards are governed by law, primarily Title 10 of the U.S. Code. Administrative boards are governed by instruction or policy. Statutory boards are convened by the Secretary of the Navy (SECNAV) and the results are approved by the President, Secretary of Defense (SECDEF), and SECNAV. Administrative boards are convened by the Chief of Naval Personnel (CNP) or the Commander, Navy Personnel Command (CNPC) and the results are approved by CNP/CNPC.

The precept is a document that is signed by the convening authority and directed to the president of the board, giving general and specific guidance to the board regarding the criteria upon which their selections should be based. The precept provides several important factors for the board to consider, such as board membership, promotion opportunity-stated percentage (i.e. 95 percent, 80 percent, etc), and any specific guidance such as the special needs of the Navy at that time. The precept is the only guidance for selection provided to a board. Using the precept as guidance, the only other sources of information about an officer allowed for consideration by a statutory board are the following:

- Personnel Record Microfiche – contains an officer’s fitness reports (FITREPS), photograph, personal awards and other matters of official record.
- Officer Summary Record (OSR)/Performance Summary Record (PSR) - an officer’s career résumé containing a summary of his or her microfiche.
- Any correspondence the officer submits to the board about their record.

No information other than what is listed above is allowed to be discussed or presented before a board.

In an effort to narrow the scope of this project, we decided to focus our effort and base our proof of concept solely upon the officer statutory board process. In particular, we focused on the promotion boards because they are the most common by far and carry the largest impact.

The mission of any board is to select those officers that are “best qualified” based on performance. Additional guidance in the precept addresses specific guidance for the board to consider in determining the best-qualified officers. The rest of the chapter will illustrate the typical promotion board process and will be broken down into three sections:

(1) Pre-board

(2) Record Review

(3) Selection.

1. Pre-Board Phase

All boards take place at the Navy Personnel Command (NPC) in Millington, Tennessee. The initial groundwork for a promotion board begins about four months before its convening date at NPC when the initial list of eligible officers is compiled and modified as required. The eligible list is continually synchronized with an official automated database to ensure consideration of all candidates and the master file is queried six weeks prior to the board convening for FITREP continuity. Messages are then sent out for any missing FITREPs. The images that are reviewed by selection boards, and the data that is presented on the OSR/PSR, come from two different sources and there are often errors and inconsistencies between the two. Researching and correcting those errors

and inconsistencies is performed by the assistant recorders who arrive and begin their work the week before the board convenes. This process is called “prep week”.

Board members arrive at NPC on the date authorized in the precept and convene the board. Board membership is secret until the board convenes and members are specifically directed not to visit detailers prior to or during board deliberations. The process is designed to ensure a level playing field for all involved. Above all, board membership is carefully balanced to represent the demographics of all the candidates in the selection zones. The precept is discussed and the board begins work on the individual record review.

2. Records Review Phase

All of the eligible officers’ data or records are divided up and impartially dispersed among the voting members of the board for review. Promotion board members review a digitized form of the official record for each eligible officer. Within each eligible officer’s digitized record, the board members review the officer’s photograph, FITREPs, OSR/PSR, and personal awards starting from the Navy Achievement Medal and higher. Education, promotion history, and board certification are some of the other areas of interest being carefully looked at during this phase. Additionally, the board members are provided and privileged information (formerly Fiche 5) on all eligible officers, if applicable. This information may be medical or punitive, such as medical board information or non-judicial punishment awarded at Article 15 proceedings and courts martial results. Most officers, however, do not have any privileged information in their record.

The board members are provided the OSR and PSR which are administrative tools used to track individual performance. Since 1995, the PSR has replaced the OSR as the sole performance-tracking tool. The PSR provides a quick snapshot of the eligible officer’s education, duty assignments, awards, and FITREP marks, while excluding the narrative section of the FITREP. An additional source of information reviewed by the board is correspondence sent by the eligible officer in the form of a letter directly to the president of the board.

The Electronic Military Personnel Records System (EMPRS) is the principal information tool used by the board members to review a candidate's record. EMPRS is an image-based information management tool that is used for processing, storing, and distributing both digital images and ASCII data. The EMPRS encompasses three distinctive modules which are the Primary Input/Output system (PRIO), the Fitness Report/Evaluation system (FITREV) and Selection Board Module (SELBD). These modules work together to create a system that allows operators to manage member records from the desktop and for selection board members to electronically evaluate personnel for promotion.

Specifically, the board members will sit at an EMPRS terminal and electronically review all of the pertinent data previously compiled and downloaded on his or her assigned candidates. The board members have the ability to not only review but also highlight, mark up, and annotate the PSR from the EMPRS terminal by means of a handwriting tool to draw lines, circles, and various other pre-configured auto shape functions that allow the reviewer/briefer the ability to highlight and specifically point out to other board members pertinent pieces of information from that record (Figure 1).

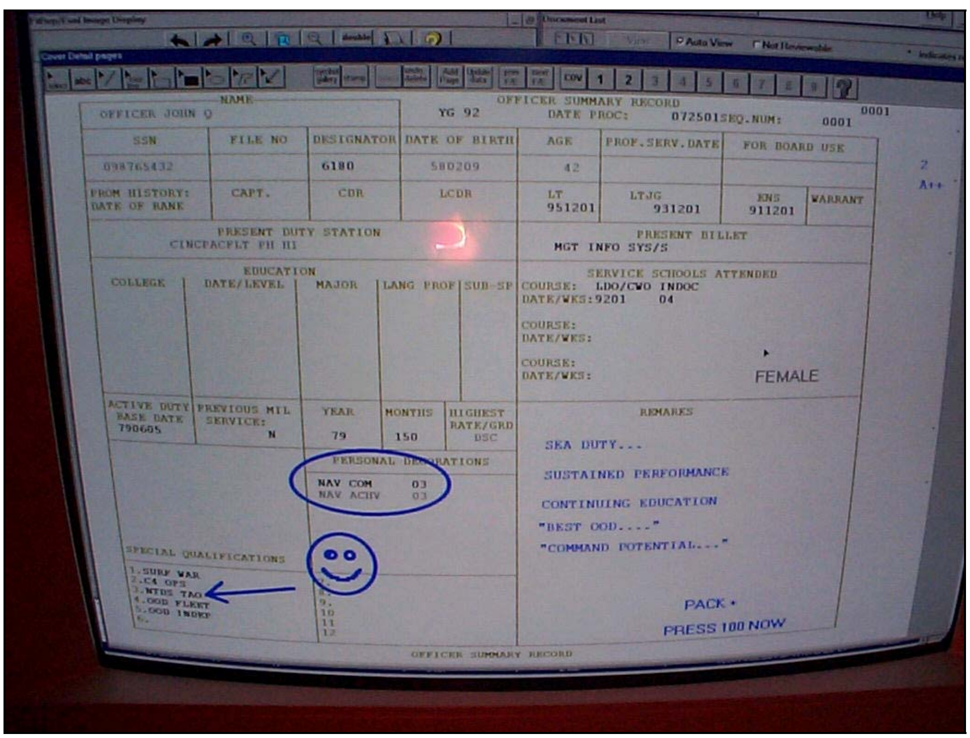

Figure 1. OSR/PSR Cover Page displayed on EMPRS. (From BUPERS Presentation)

The board carefully considers, without prejudice or partiality, the record of every eligible officer. The officers selected are those whom a majority of the members of the board consider best qualified for promotion, giving due consideration to the needs of the Navy for officers with particular skills. In addition to the standard of best qualified, all officers recommended for promotion must be fully qualified; that is, each officer must be capable of performing the duties of the next higher grade.

3. Selection Phase

After the records review phase, the board moves on to the next step – the selection phase. In this phase, the board members move into a room called "The Tank" which is a private, theatre-like room where all the members discuss and vote on candidates. The annotated OSR/PSRs are projected onto five large screens in the tank, (Figure 2) and each record is briefed by the board member who reviewed the candidate's record.

After the briefing officer has discussed the candidate and all questions have been asked and answered, each member uses a "secret ballot" computer keypad located on the arm of their seats to cast a confidence level vote for the selection of the candidate. Each member can vote either 100 percent (the member is 100 percent sure the candidate should be selected), 75 percent, 50 percent, 25 percent or 0 percent (the candidate should not be selected). After all of the votes are cast, the computer in the tank combines them into an overall confidence rating which is then displayed as an average percentage on a monitor for all the board members to see.

The confidence rating of each candidate is recorded and then ranked after all the records have been reviewed. A board member (usually the senior member or president of the board) will propose an option for selection to the entire board. The board selects a number of the records from the top scorers to be "tentatively selected" or what we'll call the TS category. The board will either vote on the motion or members will offer counter-proposals. Whichever proposal is accepted, it is accepted by a majority vote of all the members. This same scenario is repeated when the board attempts to determine which number of the bottom scoring candidates should be "dropped from further consideration" and those candidates will be placed in the DFC category. All of the candidates between the TS and the DFC categories fall into what is called the "crunch" category or zone.

Each of the candidates that fall into the "crunch" category is reviewed by a different board member than the one who originally briefed their record. Each candidate receives another review and brief in the tank and the process starts over again and is repeated until eventually the entire crunch list is diminished and all candidates have either been selected or dropped from further consideration. Several "tank" sessions are usually required before the board selects the final number of candidates they believe are best qualified for promotion. Finally, the board then completes its deliberations and votes to confirm the tentative selections.

The following sections will detail exactly what the board is looking at when voting in the "tank." This will give the reader a better understanding of how and why we designed our proof of concept model.

Figure 2. OSR/PSR info displayed in the "tank". (From BUPERS Presentation)

B. PERFORMANCE SUMMARY RECORD (PSR)

The following section will discuss how the boards use the Officer Summary Record (OSR)/Performance Summary Record (PSR) to make their selections. The OSR/PSR is an administrative tool that summarizes an officer's professional and

performance history and serves as the boards "snap shot" of the candidate's career. The board member who reviewed and annotated the candidates data on the EMPRS will brief that record in the "tank" and is the annotated OSR/PSRs that he or she is summarizing to the other board members. The OSR consists of the cover page (Figure 3) and FITREP detail pages that document the old FITREP system reports. The PSR consists of the new system reports. Let's take a look at a sample OSR/PSR and look at this notional record as a selection board member would do during a board. In an effort to keep this concise and to limit the scope of our proof of concept model, we will be reviewing only the new FITREP evaluation page (PSR) and not the old FITREP evaluation page (page 2 of the OSR proper).

1. OSR/PSR Cover Page

When a board reviews the OSR/PSR data they start with the cover page. The OSR cover page consists mainly of administrative data such as the candidates name, social security number, and career history. The comments in our example (Figure 3) are typed on the OSR/PSR image shown on the briefer's EMPRS screen and the circles and lines are drawn using computer graphics. The briefer (the board member who reviewed the candidate's record) made these remarks to highlight important points in the candidate's career to the other board members when they are voting in the tank.

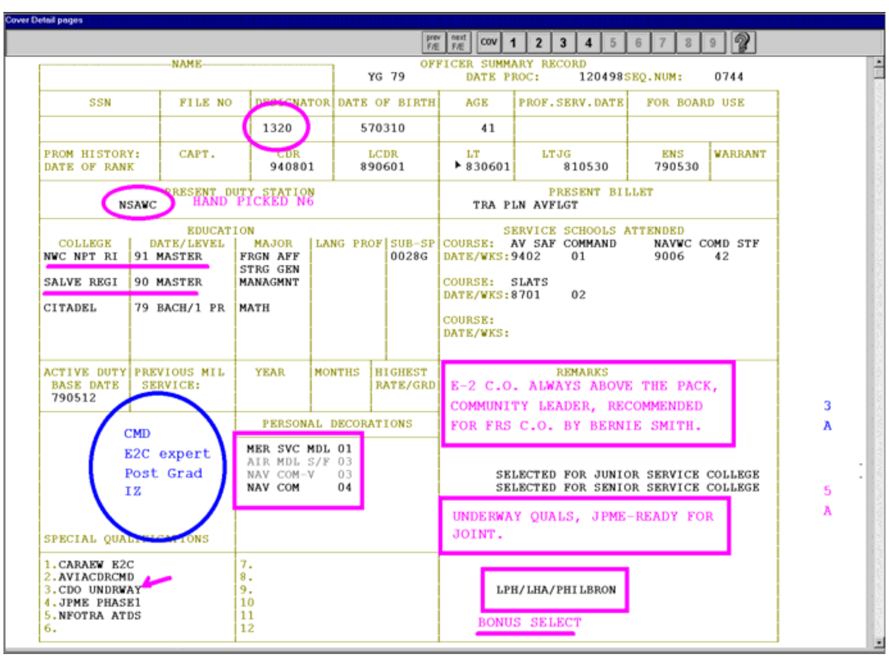

Figure 3. OSR/PSR Cover Page EMPRS view. (From BUPERS Presentation)

Apart from the standard information (name, SSN, date of birth, etc.) at the top, notice that the briefer has annotated several items that he deemed important to point out to other board members. For example, we can see that the briefer points out this candidate as an E-2 C.O. and was "ALWAYS ABOVE THE PACK, COMMUNITY LEADER, RECOMMENDED FOR FRS C.O. BY BERNIE SMITH." We can also see that another briefer (different color marks) noted and circled comments such as CMD, E2C EXPERT, POST GRAD, AND 1%, all of which could help the other board members with their decisions in the tank.

2. PSR

The following is a brief description of how the "new system" FITREPs are displayed in the PSR. The new FITREP system took affect in August 1995 and completely changed the FITREP and the look of the PSR. From Figure 4 we can see from looking at the top line and reading across from left to right, that this individual's present grade (PG) is 05. We can also see that he was the Commanding Officer of VAW-126 and that this particular reporting period (the top line) was from 090195 to 041296. The report covers a 7 month period and his reporting senior who wrote this report is T.E Zelibor whose present grade is 06 and his title at the time of the report was Commander (COM).

The remainder of the columns across the page contain the individual numbers and grade averages that make up the meat of the report. For trait grades, this candidate received two "4.0" grades and five "5.0" grades. His individual average was 4.71 and the reporting senior's (RS) trait grade average for this summary group was 4.60. This candidate was in a summary group (competitive category) consisting of 6 individuals (add 3, 1, 2 reflected in the summary line of the promotion recommendation column). The total number of Commanders (05 rank/grade) for which Capt Zelibor was the reporting senior, regardless of designator (Active, and Reserve, Line and Staff), was 7 (Top number in CUM column). Capt Zelibor's cumulative average for the 7 Commanders he had evaluated up to the end date of this report, (including the 6 in this summary group) was 4.61 (Bottom number in the CUM column). This individual was given a promotion recommendation of "Must Promote" (X under "MP") along with one other in the summary group. Three individuals in the summary group were given "Promotable"

recommendations (3 under the "PR") and two were given "Early Promote" (2 under "EP") promotion recommendations. The report was a regular ("RG") report, which maintained his record continuity (concurrent and Operational Commander Reports do not count for continuity).

From Figure 4 we can see that the two briefers who reviewed this record on the EMPRS noted that this individual was "ALWAYS ABOVE THE PACK AS C.O. AND ALWAYS RANKED." Also annotated was the fact that he was a "CLF SILVER ANCHOR WINNER" during the top reporting period. The heavy line drawn across the middle of the report is just separating two different Commands.

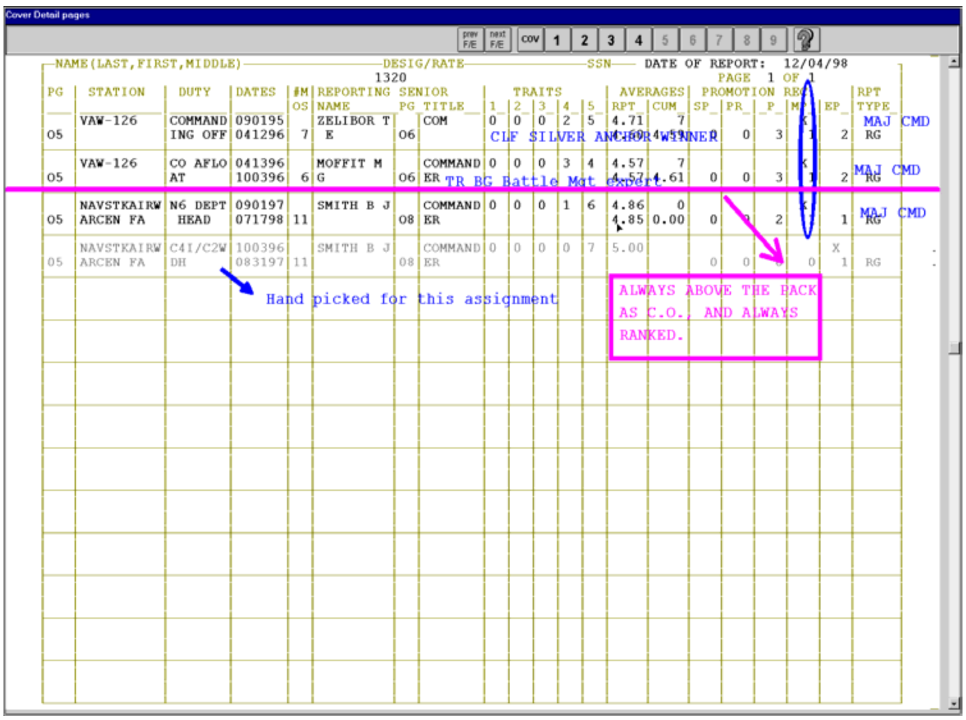

Figure 4. PSR with briefers' annotated marks. (From BUPERS Presentation)

3. Summary

In this chapter we have reviewed the Promotion Board process with the intent to explain the basics of the procedures to the reader who has had little or no prior knowledge of, or experience with, the Navy's promotion process. We believe this will provide a solid foundation from which the reader may better derive a thorough understanding of our methodology and proof of concept model. From the last section it should be fairly clear to the reader why we believe there could be a more effective way in

which to display the OSR/PSR information to the board members in the tank. Much of the pertinent information is quantitative, convoluted, and widely dispersed across the five screens in the tank. The following chapters will explain the theory behind our proposal, an economic comparison of the current system to what we are proposing, and a look at the proof of concept prototype followed by the conclusion and recommendations.

III. LITERATURE REVIEW

A. INTRODUCTION

The current method for displaying a candidate's personnel record for promotion or selection decisions relies heavily on human cognition to process tabular OSR/PSR data into the required information used for comparison and decision making. The majority of the information is numerical and is often spread out across different places among the five large screens within the tank. Our challenge is how can we arrange the data graphically or visually so that it is aesthetic to the viewing board members in order to allow them to more easily correlate all of the data quickly and objectively? Can we make it web-based so that some of the extremely time consuming manual processes such as scanning documents onto the system or having to separately download data into the tank, be eliminated completely? How do we effectively measure this to see if it's worth the effort to redesign? In other words how do we go about measuring the change in performance from the "as is" baseline process in use today against our proposed "to be" model of tomorrow?

This chapter will review the literature we used in order to answer the previous questions. Section B discusses the Knowledge Value Added (KVA) methodology that was developed by Dr. Thomas J. Housel and Dr. Valery Kanevsky. KVA is essentially a performance metric that provides a means for objective measurement of the relationship between knowledge and value in organizational processes. Section C will detail the best practices for effectively displaying quantitative information graphically as seen by one of the renowned authorities in that field, Edward R. Tufte.

B. KNOWLEDGE VALUE ADDED (KVA)

Omar A. El Sawy, in his book *Redesigning Enterprise Processes for e-Business*, explains that one of the central tenets of the Knowledge Value-Added (KVA) methodology is that:

> When a process is redesigned to be more knowledge-creating, it is often hard to measure the added value to the customer of the process. One of the characteristics of such a redesign principle is that it causes the business process to learn more from the participants it interacts with each time there is an interaction. Thus the value of the process increases over time as intellectual capital through repeated execution, even though initially there is no immediate added value for the customer. It is difficult at the design stage to measure what the return on redesigning the process might be. The quicker that the new knowledge in the process can be translated into value that the customer is willing to pay for (whether through this business process or a related one), the more effective the business process design is (El Sawy, 2001).

How can we adequately measure the effectiveness of what we're proposing? It would be very difficult, to measure whether or not the board members were making better decisions with the redesigned process. Although the redesigned process would result in shorter board times and thus resulting in less costs, we would be remiss if we were to base the effectiveness solely on time savings. Much of the change that we need to measure is intrinsic and may not be immediately apparent. For example, better decisions made in the promotion and assignments processes of today may lead to an improved quality of life and higher retention rates for tomorrow.

1. Knowledge Value Added Theory

The method we chose to measure the benefits of greater efficiency in the decision process is the Knowledge Value Added (KVA) methodology. This methodology is beneficial to non-profit organizations because it presupposes knowledge as a surrogate for value and therefore can be used independent of profit generation. Because of this and the fact that cutting costs and reducing head count were not viable options for our proof of concept, KVA was chosen because it enables managers to measure the performance of corporate or community knowledge assets whether the knowledge is deployed in information technology (IT) or resident within employees' heads.

KVA analysis produces a Return on Knowledge (ROK) ratio to estimate the value added by given knowledge assets regardless of where they are located within the organization. The essence of KVA is that knowledge utilized in organizations' core processes is translated into numerical form. This translation allows allocation of revenue in proportion to the value added by the knowledge as well as the cost to use that

knowledge. Tracking the conversion of knowledge into value while measuring its bottom line impacts enables managers to increase the productivity of these critical assets (Housel and Bell, 2001).

KVA provides a methodology for allocating revenue and cost to an organization's core processes based on the amount of change each produces. KVA standardizes the output of all processes by describing the output in terms of the units of knowledge required to produce it. Notably, the knowledge required to make these changes is a convenient way to describe the conversion process. Knowledge is the know-how required to produce process outputs, process instructions, or in our case, process decisions. This kind of knowledge is proportionate to the time it takes to learn it.

2. Knowledge Value Added Method

The KVA method is extremely beneficial to organizations because it is simple enough to be applied in seven steps yet it is robust enough to produce a desired level of granularity should the organization desire a more comprehensive view of their processes. Housel and Bell offer three different ways to establish the value of knowledge embedded in the organizations core processes (Table 1).

Steps	Learning time	Process description	Binary query method
1.	Identify core process and its subprocesses.		
2.	Establish common units to measure learning time.	Describe the products in terms of the instructions required to reproduce them and select unit of process description.	Create a set of binary yes/no questions such that all possible outputs are represented as a sequence of yes/no answers.
3.	Calculate learning time to execute each subprocess.	Calculate number of process instructions pertaining to each subprocess.	Calculate length of sequence of yes/no answers for each subprocess.
4.	Designate sampling time period long enough to capture a representative sample of the core process's final product/service output.		
5.	Multiply the learning time for each subprocess by the number of times the subprocess executes during sample period.	Multiply the number of process instructions used to describe each subprocess by the number of times the subprocess executes during sample period.	Multiply the length of the yes/no string for each subprocess by the number of times this subprocess executes during sample period.
6.	Allocate revenue to subprocesses in proportion to the quantities generated by step 5 and calculate costs for each subprocess.		
7.	Calculate ROK, and interpret the results.		

Table 1 Three Approaches to KVA (From Housel and Bell)

Although the binary query method is usually the most precise method, it is also the most time intensive and is usually only used for situations requiring a high degree of accuracy and granularity. The method we chose for our Proof of Concept is the Learning Time method. This method allows those who use it to establish rough-cut estimates of the value of knowledge within processes. It can be accomplished more quickly than the binary query method and is targeted at the aggregate level of analysis. An example of a high-level aggregate KVA analysis is shown in Table 2.

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10	Col. 11
Core areas	Rank in terms of difficult to learn (1=easiest, 3=hardest)	Relative learning time (total = 100 months)	Number of employees	Percentage of automation	Amount of knowledge embedded in automation	Total amount of knowledge	Percentage of knowledge allocation	Annual revenue allocation (in millions of U.S. dollars)	Annual expense (in millions of U.S. dollars)	ROK
S&GA	1	20	855	80%	13,680	30,780	34.18%	$ 82.7	$118.8[a]	70%
Operations	3	45	600	60	16,200	43,200	47.98	116.1	197.2[b]	59
Management	2	35	255	80	7,140	16,065	17.84	43.2	51.0[c]	85
Total		100	1,710[d]		37,020	90,045	100%	$242.0		

Table 2 High-level Aggregate KVA Analysis (From Housel and Bell)

Table 2 shows an example of a company's results of a seven step high-level KVA analysis. Right away managers are able to determine the relative performance of the core functional areas in terms of ROK. The results would serve as a starting point from which a more detailed KVA analysis could be done to identify knowledge embedded in sub-processes and to help managers make improved decisions on how to increase the company's profits.

Learning Time (LT) has been established as a fast and appropriate way to measure the amount of knowledge contained in any given process. The amount of knowledge embedded in a process corresponds to the amount of time necessary for an average person to learn how to complete the process properly. The knowledge can also be represented by the process instructions required to produce the process output effectively. Learning time is in proportion to the amount of knowledge learned. In this manner, learning time can be used as a common-sense indicator of the amount of knowledge

embedded within a given process. Usually the Subject Matter Experts (SME) for a particular process can provide actual realistic estimates of the learning time required for a given process based on formal and informal training times, experience on the job, employee interviews, training manuals, and programs.

3. KVA Example

The following is a short and extremely simple example of KVA and how it works, taken from Housel and Bell's *Measuring and Managing Knowledge*. In the Widget Company, there is one person, the owner, who makes and sells widgets. This person knows all there is to know in order to make and sell widgets for $1. The owner's sales-production knowledge can be used as a surrogate for the dollar of revenue generated by his application of the core process knowledge. We can determine how long it takes the widget company owner to transfer all the necessary sales and production knowledge to a new owner. Further, we can use these leaning times to allocate the dollar of revenue between the sales and production processes. For simplicity sake lets say that it takes 100 hours for someone to learn a new process with 70 hours spent learning how to make the widget and 30 hours learning how to sell it. This would indicate that 70 percent of the knowledge and value added was contained on the production process and 30 percent in the sales process. It would follow that $.70 of the revenue would be allocated to production knowledge and $.30 to sales knowledge.

All that would be left to do in this example would be to determine how much it costs to use the sales and production knowledge and then we would have a ratio of knowledge value added to knowledge utilization cost. In other words, we can measure return on knowledge (ROK). For the sake of argument, we will assume that the total cost to sell and produce a widget was $.50: with $.25 for sales and $.25 for production. The basic approach here is to find out how much it costs to use the sales and production knowledge. In this case, the cost is directly tied to how long the new owner spends performing each process. As it turns out, in this case, the new owner spends the same amount of time to do both and, therefore, the cost to use the knowledge of each process is the same.

Based on the estimates for the distribution of revenue and cost, we would generate an estimate of the ROK. We would conclude that the production process is a more

productive use of the knowledge asset (ROK = .7/.25=280%) that the sales process (ROK=.30/.25 = 120 percent).

4. KVA Summary

KVA provides the organization with a way of making decisions on how best to shift or eliminate knowledge as in the case of whether or not to automate a core process. The key issue, and one that applies to our case, is how to redeploy knowledge from people and procedures or work rules in to IT so that it can be executed more rapidly, therefore more often, and at a lower cost. If the ROK of a given process is not improved with the implementation of the automation, then steps must be taken to improve its functionality and performance.

The same view may be extended to estimate the amount of knowledge contained in IT. To do this, the organization must choose IT outputs within the core process and then ask the resident SME to estimate the time necessary for learning how to generate the same outputs. In other words, he or she should estimate how long it would take to do the same process without the IT. How long would it take to teach the average person to produce the same output manually without the IT? Most likely, it would take much longer for the average person to produce the same outputs but what really needs to be determined is how long it would take that person to learn to produce the outputs (i.e. the learning time estimate).

In this way, IT is just another layer of process knowledge. KVA also allows the organization to determine that important question of what is its return on IT? KVA allows the organization to obtain a true snapshot of the return it's getting from IT. Because the numerators and denominators come from different data sources (real revenues and costs) managers won't be able to manipulate cost (i.e. the denominator) to obtain the numerator (e.g. cost savings or cost avoidance) so that a false return would be generated.

C. BEST PRACTICES FOR VISUALIZATION TECHNIQUES

> What we see is not always what we think we see. We must ensure that what we portray is not misleading or misunderstood, and that we are conveying the intended message (Brown, 1995).

This section will explore the current best practices for displaying quantitative information and make recommendations on how to most effectively and objectively display the OSR/PSR information. One of the greatest benefits of data visualization is the sheer quantity of information the audience can rapidly interpret if the visual data is presented well. We have chosen to follow the theoretical research of Edward R. Tufte because of his renowned expertise in this field.

This chapter outlines Edward Tufte's pioneering work on the use of visual graphics to display quantitative information and it mainly consists of text and ideas taken from three of his books on this subject matter. We have included a few diagrams as examples but the reader should examine the books in order to get a full understanding and appreciation of the graphics and concepts he introduces.

> Modern data graphics can do much more than simply substitute for small statistical tables. At their best, graphics are instruments for reasoning about quantitative information. Often the most effective way to describe, explore, and summarize a set of numbers – even a very large set – is to look at pictures of those numbers. Furthermore, of all methods for analyzing and communicating statistical information, well-designed data graphics are usually the simplest and at the same time the most powerful (Tufte, 2001).

1. Graphical Principles

In his book *The Visual Display of Quantitative Information*, Edward R. Tufte explains that excellence in statistical graphics consists of complex ideas that are communicated with clarity, precision, and efficiency. He further notes that graphical displays should:

- Show the data.
- Induce the viewer to think about the substance rather than about methodology, graphic design, the technology of the graphic production or something else.
- Avoid distorting what the data have to say.
- Present many numbers in a small space.
- Make large data sets coherent.
- Encourage the eye to compare different pieces of data.
- Reveal the data at several levels of detail, from a broad overview to the fine structure.
- Serve a reasonably clear purpose: description, exploration, tabulation, or decoration.
- Be closely integrated with the statistical and verbal descriptions of a data set.

In order to gain the most benefit from redesigning the promotion board displays so that the data is clear, easily understood, and not biased in any manner, we adhered to Tufte's principles of graphical excellence. These principles are as follows:

- Graphical excellence is the well-designed presentation of interesting data – a matter of substance, of statistics, and of design.
- Graphical excellence consists of complex ideas communicated with clarity, precision, and efficiency.
- Graphical excellence is that which gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space.
- Graphical excellence is nearly always multivariate.
- Graphical excellence requires telling the truth about the data.

a. Graphical Integrity

Tufte's works are appropriate for our study because he has developed a consistent approach to the display of graphics which enhances its dissemination, accuracy, and ease of comprehension. Most importantly, he stresses that you cannot gain graphical excellence without telling the truth about the data which is paramount in our proposal for the redesigned promotion displays.

He explains that the problem lies in presenting large amounts of information in a way that is compact, accurate, adequate of the purpose, and easy to understand. Specifically, a designer must show cause and effect, insure that the proper comparisons are made, and achieve the valid goals that are desired. A major problem with presenting the visual display of quantitative information is the misperception of that data by the viewer. Different people see the same objects somewhat differently and context-dependent perceptions change with experience . Another factor that could distort the data involves miscommunication. A person's perception of an object can change depending on what others have already said.

In order to reduce these effects, the designer needs to strive for uniformity in graphics and assurance that the representation accurately depicts the target numbers. Tufte mentions two goals that if followed, may alleviate these problems.

- The representation of numbers, as physically measured on the surface of the graphic itself, should be directly proportional to the numerical quantities represented.

- Clear, detailed, and thorough labeling should be use to defeat graphical distortion and ambiguity. Write out explanations of the data on the graphic itself. Label important events in the data.

Tufte theorizes that in order to get an idea of how much a graphic is in violation of the first principle, one could measure it by use of the "Lie Factor" which is the size of effect shown in the graphic divided by the size of effect in data [=(size of graphic)/(size of data)]. The Lie Factor is used to exaggerate differences or similarities. If the Lie Factor is equal to one, then the graphic is probably doing an adequate job of accurately representing the numbers. If the Lie Factor is greater than 1.05 or less than .95, then substantial distortion is possibly involved. As an example, Tufte uses a newspaper that reported that the U.S. Congress and the Department of Transportation had set a series of fuel economy standards for automobile manufactures, beginning with 18 miles per gallon in 1978 and moving incrementally up to 27.5 miles per gallon by 1985, an increase of 53 percent. However, when the magnitude of the change from 1978 to 1985 is shown in the graph by the relative lengths of the two lines, it reveals a difference of 783 percent. Thus, the numerical change of 53 percent is presented by two lines that changed 783 percent, yielding a Lie Factor of 14.8 percent, well beyond the bounds of acceptability.

The Lie Factor could be a quick and easy method for gaining insight into the scale of the graphics used to depict candidates' PSR information to the board. For example, suppose a candidate had a trait average of 4.80 for a reporting period and during the subsequent period, he had a report average 4.60 for a negative .20 difference which is a 4.16 percent decrease of the first mark of 4.80. If the graph depicting that difference changed from 1.25 inches to 1.00 inch, we calculate a decrease of a 20 percent for a Lie Factor of (.20/.0416 = 4.81) which, in accordance with Tufte's advice is substantially distorted because it is greater than the 1.05 upper limit that he recommends. In this case you would most likely increase the scale of the graph (otherwise the difference may not be visible to the viewers) which would have the effect of decreasing the difference or variation being shown.

The accurate depiction of data also means that design variation should not affect or distort the data being displayed. In other words, one should not change the data in order to make the graphic look nice. The compounding of design variation with data variation over the surface of a graphic leads to ambiguity and deception, because the eye may mix up changes in the design with changes in the data. The graphic should follow the principle of showing data variation, not design variation.

Another way to confuse data variation with design variation is to use the space to show one-dimensional data. A common mistake is to use areas to show magnitudes and falsely varying both dimensions simultaneously in response to changes in one-dimensional data. Vast ambiguities arise when viewers perceive a two-dimensional surface and then convert that perception into a non-dimensional number. The difference in physical area on the surface of a graphic does not reliably produce appropriately proportional changes in perceived areas. This problem is even worse when adding a third dimension to the graphic. The use of two or three varying dimensions to show one dimensional data is not an efficient technique and often leads to ambiguity in perception and should be avoided by abiding by the following principle: The number of information–carrying (variable) dimensions depicted should not exceed the number of dimensions in the data.

Tufte writes that to be truthful and revealing, data graphics must bear on the question at the heart of quantitative thinking: “Compared to what?” The emaciated, data-thin design should always provoke suspicion, for graphics often lie by omission, leaving out data sufficient for comparisons. The principle: Graphics must not quote data out of context.

On the issue of Graphical Integrity, Tufte points out that graphical proficiency requires three entirely different skills: the substantive, statistical, and artistic. If statistical integrity and graphical sophistication are to be achieved, then the team of designers should include experts in the area of substantive and quantitative information. Don’t leave the design work solely up to the graphic artists or you may end up with graphics that (l) lie; (2) employ only simple designs; (3) and do not capture the real news of the data.

To summarize, in order to maintain graphical integrity it is important for the designer to ask the right questions:

- Does the display tell the truth?
- Is the representation accurate?
- Are the data documented?
- Do the display methods tell the truth?
- Are the appropriate comparisons, contrasts, and contexts shown?

2. Theory of Data Graphics

a. Data-Ink and Graphical Redesign

Tufte's fundamental principle of good statistical graphics is: "Above all else show the data." This principle is the basis for a theory of data graphics. The majority of ink on a graphic should represent data-information, with the ink changing as the data changes. Tufte explains that data-ink is the non-erasable core of a graphic, the non-redundant ink arranged in response to variation in the numbers represented and should be maximized at all times. The more of the graphic that is devoted to data, the better off it will be in displaying that data.

In conjunction with maximizing the data to ink ratio, he also writes that one should erase the data ink that is not representing data. Ink that doesn't depict statistical information doesn't have much use to the viewer of the graphic and could possibly cover up or clutter up useful data. One way to reduce unnecessary data ink is to look at the bilateral symmetry. Is there a chance that the space consumed in a graphic can be halved without losing any important information? Unless it serves a distinct purpose, redundancy of the same data should be avoided. It is important to be able to edit the data after it has been displayed in order to weed out the unnecessary or redundant data-ink so that the critical data is obviously clear.

These five principles in the theory of data graphics produce substantial changes in graphical design. These principles apply to many graphics and yield a series of design options through cycles of graphical revision and editing. The five principles are:

- Above all else show the data
- Maximize the data-ink ratio
- Erase non-data ink
- Erase redundant data-ink
- Revise and edit.

b. Chart Junk: Vibrations, Grids, and Ducks

Throughout his books, Tufte mentions how to achieve graphical excellence by avoiding many graphical mistakes or methods .

Sometimes a designer of a graphic unintentionally engrosses the body of the graphic with a lot of ink that serves no useful purpose and doesn't tell the viewer anything new. The purpose of superfluous decoration may have been to make the graphic appear more scientific, to enliven the display, or to give the designer an opportunity to exercise artistic skills. Whatever the reason, the excess is all non-data-ink or redundant data-ink, and is what Tufte refers to as chart junk. Chart junk consists of decorative elements that provide no data and cause confusion. This graphical decoration is prevalent in technical publications as well as in commercial and media graphics and is easier to produce than the hard work required to produce intriguing numbers and securing evidence. Most chart junk doesn't involve artistic considerations or motivations, rather it just naturally evolves and pervades by use of conventional graphical bits and pieces that are routinely used in displays. These bits and pieces consist of over-busy grid lines and excess ticks, redundant representations of the simplest data, the debris of computer plotting, and many of the devices generating design variation.

Tufte points out three widespread types of chart junk that are typically abundant in scientific and technical research these days. They are the unintentional optical art, the dreaded grid, and the graphical duck.

Unintentional optical art is dependent upon moiré effects, in which the design interacts with the physiological quiver of the eye to produce the disturbing manifestation of vibration and movement. This disturbing effect extends beyond the ink of the design to the whole page. It is not a good idea to draw up statistical graphics that appear to shimmer. As bad as this moiré vibration is in clouding the flow of information, it is even more abundant today due to the ability to easily and quickly create the ill effects with computer programs such as Excel and Power Point. “The handbooks and textbooks

of statistical graphics, along with the user's manuals for computer graphics programs, are filled up with vibrating graphics, presented as exemplars of design" (Tufte, 2001).

Another form of chart junk is that of the grid. If the designer should attempt to use any form of grid it should be very light or completely suppressed showing only an implicit presence so as not to interfere with the target data. Grids are used for the initial plotting and should not show up on the final graphic. Grids contain no information, tend to clutter up the graphic, and generate graphic activity unrelated to data information.

When a graphic is taken over by decorative forms or computer debris, the data measures and structures become design elements, or the overall design purveys graphical style rather than quantitative information, then that graphic may be called a duck in honor of the duck-form store, "Big Duck." For this building the whole structure is itself decoration, just as in the duck data graphic. (Tufte, 2001)

Designers of data graphics should seek to use new technology in a way that present data in a meaningful way rather than quickly and massively spitting out graphics that just look cool. Chart junk can turn a mediocre graphic or chart into a total disaster, but it can never replace or effectively represent a thin data set. A designer should never use chart junk, including moiré vibration, the grid, or the duck.

c. Data-Ink Maximization and Graphical Design

By using the previous principles, it is possible to not only edit old designs but derive new graphical forms as well. Tufte uses several examples where he shows before and after effects of simple graphs to show that his theory of data graphics is correct. (See Figure 5). In some of his examples, the observed increases in efficiency, or how much of the graphic's ink carries information, were sometimes quite large. In several cases, the data-ink ratio increased from .1 or .2 to nearly 1.0. These transformed designs were less cluttered and could be shrunk down more easily than the originals. But are these transformed ideas better? Tufte answers this question by saying:

- They are better within the principles of the theory, for more information per unit of space and per unit of ink are displayed. It's a significant gain when you consider that the history of devices for communicating information is written in terms of increases in efficiency of communication and production.
- Graphics are almost always going to improve as they go through editing, revision, and testing against different design options. The principles of maximizing data-ink and erasing generate graphical alternatives and also suggest a direction in which revisions should move.
- Then there is the audience: will those looking at the new designs be confused? Some of the designs are self-explanatory. The chance of a member of the audience being confused is remote. Nothing is lost to those who are puzzled by the changes and something is gained by those who do understand it. Moreover, it is a frequent mistake in thinking about statistical graphics to underestimate the audience.
- Some of the new designs may appear odd, but this is probably because we have not seen them before. The conventional designs for statistical graphics that have been viewed thousands of times where as the new designs have not. In time and with use the new designs would become just as reasonable as the old.

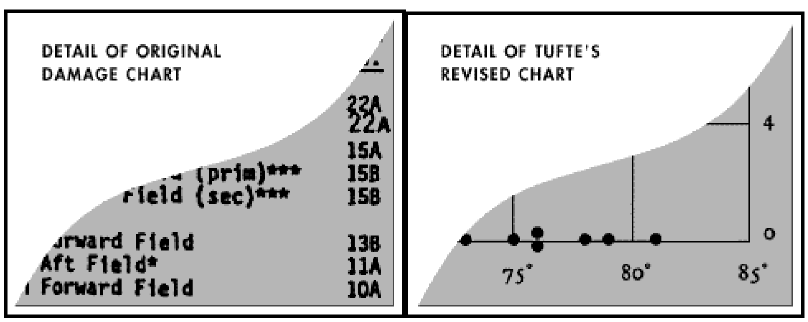

Figure 5. Before and after versions of numerical charts. (From Salon)

d. Multi-functioning Graphical Elements

The same ink should often serve more than one graphical purpose at a time. A graphical element may carry data information and also perform a design function usually left to non-data-ink. Or it might show several different pieces of data. Such multi-functioning graphical elements, if designed with care and subtlety, can effectively display complex, multivariate data. (Tufte. 2001) The principle is: Mobilize every graphical element, perhaps several times over, to show the data.

In other words, use the graphic segment to show or portray more than one item of data. Graphical structures can often serve several purposes at once. For example, the stem and leaf plots display sequences of numbers which directly portray structure by

the physical length of each sequence. Tufte contends that the designers of such graphical elements must be careful because multi-functioning elements tend to generate graphical puzzles, with encoding that only the designer can figure out. The designers must strive for enhancing graphical clarity in the face of complexity when developing multi-functioning elements.

Those graphical elements that actually locate or plot data in a graph or chart are called the data measure. For example, the bars of a bar-chart, the dots of a scatter-plot, the dots and dashes of a dot-dash-plot, or the blots of a blot map are data measures. The data grid itself may be the data, revealing both the values and the coordinate system at the same time. The ink that makes up the data measure can itself carry data, for example, the dots of the scatter-plot can take on different shading in response to a third variable. This rule can also be used with data-based coordinate lines as well. Why not use that ink to show data in the form of data-based labels?

In many graphics the coordinate labels are separated from the data measures. Because of that the eye of the viewer must move back and forth between the path formed by the data and the coordinate positions arrayed along the margins of the graphic. It is possible that this eye work could be eliminated entirely by turning the coordinate labels into data measures, another double functioning maneuver.

e. Colors

Much of Tufte's books talk about the effect that colors have on graphics. However, much of what he writes about does not apply directly towards the graphics that we are concerned with in this study so the we have tried to compile only the relevant applications of using color as they may apply in the redesign of the promotion displays.

> Of course color brings to information more than just codes naming visual nouns – color is a natural quantifier, with a perceptually continuous (in value and saturation) span of incredible fineness of distinction, at a precision comparable to most measurement (Tufte, 1990).

Color use can greatly enhance data comprehension and can convey multi-dimensional values effectively. Color grids are a form of layering which provides context but which should be unobtrusive and muted. Pure bright colors should be reserved for small highlight areas and almost never used as backgrounds. Colors can be use as labels,

as measures, and to imitate reality as in the blue lakes in maps. Color spots against a light gray are also effective.

Despite these benefits of using colors in displaying information, the designer must avoid using colors in a way that generates graphical puzzles. Despite our experiences with the spectrum in science textbooks and rainbows, the mind's eye does not readily give a visual ordering to colors, except possibly for red to reflect higher levels than other colors (Tufte 2001). Attempts to give colors an order often requires the viewer to mentally decode the color scheme, trying to recall what the different colors represented, and to look back at the legend to clarify it.

The success of gray compared to the visually more spectacular color gives us a lead on how multi-functioning graphical elements can communicate complex information without turning into puzzles. The shades of gray provide an easily comprehended order to the data measures. This is the key. Central to maintaining clarity in the face of the complex are graphical methods that organize and order the flow of graphical information presented to the eye.

So what colors should we use in order to represent and illuminate information? Tufte suggests the use of colors found in nature, especially those on the lighter side, such as blues, yellows, and grays of sky and shadow.

> Nature's colors are familiar and coherent, possessing a widely accepted harmony to the human eye – and their source has a certain definitive authority. A palette of nature's colors helps suppress production of garish and content-empty color junk. Local emphasis for data is then given by means of spot highlights of strong color woven through the serene background (Tufte, 1990).

In their book *Visualization: Using Computer Graphics to Explore Data and Present Information*, the authors explain that in displays of graphs and charts, there are overlapping lines, grids, background, and text. Thus a designer needs to select colors so that the various pieces of information are distinguishable even when they are overlapping. "The connotation of color is critical in monitoring applications because the viewer must react quickly to the appearance of a particular color in a given location." (Brown, et al. 1995) Table 3 and Table 4 reproduced from their book show the best and

worst color combinations, as determined from a study where at least four of sixteen participants accepted or rejected each color combination.

Best Color Combinations
(N = 16)

Background	*Thin Lines and Text*	*Thick Lines and Panels*
White	Blue (94%), Black (63%), Red (25%)	Black (69%), Blue (63%), Red (31%)
Black	White (75%), Yellow (63%)	Yellow (69%), White (50%), Green (25%)
Red	Yellow (75%), White (56%), Black (44%)	Black (50%), Yellow (44%), White (44%), Cyan (31%)
Green	Black (100%), Blue (56%), Red (25%)	Black (69%), Red (63%), Blue (31%)
Blue	White (81%), Yellow (50%), Cyan (25%)	Yellow (38%), Magenta (38%), Black (31%), Cyan (31%), White (25%)
Cyan	Blue (69%), Black (56%), Red (37%)	Red (56%), Blue (50%), Black (44%), Magenta (25%)
Magenta	Black (63%), White (56%), Blue (44%)	Blue (50%), Black (44%), Yellow (25%)
Yellow	Red (63%), Blue (63%), Black (56%)	Red (75%), Blue (63%), Black (50%)

Table 3 Best Color Combination. (From Brown, et al.)

Worst Color Combinations
(N = 16)

Background	*Thin Lines and Text*	*Thick Lines and Panels*
White	Yellow (100%), Cyan (94%)	Yellow (94%), Cyan (75%)
Black	Blue (87%), Red (37%), Magenta (25%)	Blue (81%), Magenta (31%)
Red	Magenta (81%), Blue (44%), Green (25%), Cyan (25%)	Magenta (69%), Blue (50%), Green (37%), Cyan (25%)
Green	Cyan (81%), Magenta (50%), Yellow (37%)	Cyan (81%), Magenta (44%), Yellow (44%)
Blue	Green (62%), Red (37%), Black (37%)	Green (44%), Red (31%), Black (31%)
Cyan	Green (81%), Yellow (75%), White (31%)	Yellow (69%), Green (62%), White (56%)
Magenta	Green (75%), Red (56%), Cyan (44%)	Cyan (81%), Green (69%), Red (44%)
Yellow	White (81%), Cyan (81%)	White (81%), Cyan (56%), Green (25%)

Table 4 Worst Color Combinations. (From Brown, et al.)

f. Data Density and Small Multiples

Graphics are best when they represent very dense and rich data sets. Within a small area, our eyes can make an extraordinary number of distinctions. For example, by using very light grid lines it is easy to locate 625 points in one square inch,

or equivalently, 100 points in one square centimeter. It would be wise then in the design of statistical graphics to take advantage of the eye's ability to detect large amounts of information in small spaces. But how does one gauge how much information the graphics should show? Tufte calls this the measure of data density. Taking into account the size of the graphic in relation to the amount of data it displays yields the data density:

Data density = (no. of entries in data matrix)/(area of graphic)

Figure 6 of the New York City weather history is a good example of a graphic with a high data density of 181 numbers per square inch (28 per square centimeter).

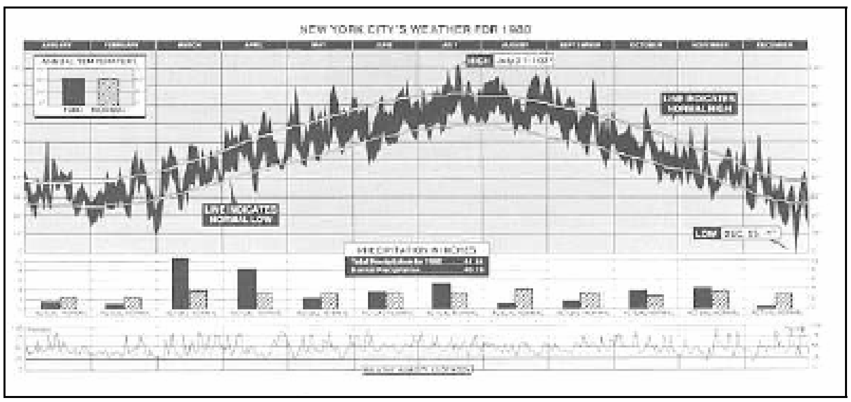

Figure 6. New York Weather History (From Tufte)

Data graphics should be based on large rather than small data matrices and have a high rather than low data density. More information is better than less information, especially when the marginal costs of using and interpreting additional information are small, as they are for most graphics. Tufte also recommends that the simple items should left out in tables or in the text. Graphics can give a sense of large and complex data sets that cannot be managed in any other way. If it becomes overcrowded (although several thousand numbers represented isn't usually a problem) a variety of data reduction techniques – averaging, clustering, smoothing – can thin the numbers out before plotting. It is important to realize that summary graphics can emerge from high-information displays, but there is nowhere to go if we begin with a low-information design.

Graphical designs that are data- rich give context and credibility to statistical evidence. Viewers may question low-information designs by wondering what is

left out, what is hidden, and why are we shown so little. Graphics that are high density will help the viewer to compare parts of the data by displaying much information within the view of the eye. The principle to remember here is: Maximize data density and the size of the data matrix, within reason.

One must be careful when designing high- information graphics because as the volume of data increases, data measures must shrink (smaller dots for scatter plots or thinner lines for time series, etc.) The appearance and disorder of chart junk, non-data-ink, and redundant data-ink can result in even greater disaster in data-rich designs. The way to increase data density without having to enlarge the data matrix is to reduce the area of the graphic. Tufte points out that many data graphics can be reduced in area to half their currently published size with virtually no loss in legibility and information.

In review, good graphics are:

- Comparative
- Multivariate
- High density
- Able to reveal interactions, comparisons, etc.
- Drawn almost entirely with data-ink

g. Aesthetics

Tufte writes that graphical elegance consists of design simplicity , complexity, and truth of data. Graphics that are visually striking generate power from content and interpretations beyond the immediate display of some numbers. To attain attractive displays of statistical information a graphic should:

- Have a properly chosen format and design .
- Use words, numbers, and drawing together.
- Reflect a balance, a proportion, and a sense of relevant scale.
- Display an accessible complexity of detail.
- Often have a narrative quality; a story to tell about the data.
- Be drawn in a professional manner, with the technical details if production done with care.
- Avoid content-free decoration, including chart junk.

Tufte explains that words and pictures belong together and sometimes viewers need help that words can provide. It is almost always helpful to write little messages on the plotting field to explain the data, to label the outliers and interesting data

points, to write equations and sometimes tables on the graphic itself, and to integrate the captions and legend into the design so that the eye is not required to dart back and forth between textual material and the graphic. The size of type on and around graphics can be quite small, since the phrases and sentences are usually not too long – and therefore the small type will not fatigue viewers the way it does in lengthy texts. The principle of data/text integration is: Data graphics are paragraphs about data and should be treated as such.

When graphical elements are together and their proportions are in balance, it looks better and ensures that an integrated quality and appropriate visual linkage exists between them. Lines in data graphics should be thin. The orthogonal intersection of lines of different weights is an effective aesthetic device as well.

The design of data graphics should tend toward the horizontal rather than the vertical. Tufte believes that a display greater in length than height has advantages due to the fact that our eye is naturally practiced in detecting deviations from the horizon, and graphic design should take advantage of this fact. Horizontally stretched time series are more accessible to the eye. The analogy to the horizon also suggests that a shaded, high contrast display might occasionally be better that the non-shaded lines that resemble a floating snake. It is also easier to read words that read from left to right on a horizontally stretched plotting field. A longer horizontal axis helps to elaborate the workings of the causal variable in more detail. How much wider should it be? Tufte writes that a good design would move toward the horizontal about 50 percent wider than tall.

3. Conclusion

The importance of a well thought-out, and coherent design of the graphics for the promotion visual displays cannot be overstated. The rapid and accurate transfer of information by use of sound graphical principles can have a profound effect on future of the Navy’s promotion system. In determining the design of choice, the principles set forth above should help generate design options and guide choices among options. It is Tufte’s belief that these principles should be applied flexibly because they are not logically or mathematically certain and it would be better to violate any principle than to place graceless or inelegant marks on paper.

What is to be sought in design for the display of information is the clear portrayal of complexity. Not the complication of the simple; rather the task of the designer is to give visual access to the subtle and the difficult – that is, the revelation of the complex (Tufte, 2001).

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IV. DATA COLLECTION AND ANALYSIS

A. INTRODUCTION

The proof-of–concept (POC) framework for this study is the Navy's current officer promotion/selection process. In order to answer the principle research question we have developed a POC prototype visualization solution through the use of COTS software and technology in order to display, at a minimum, visualization concepts and capabilities currently available. This prototype uses a simple notional relational database (Microsoft Access) and simulates the current system's input and outputs. Using three-tier architecture, the prototype will extract the data from the database and display an improved visual display for the board to interpret and compare. Additionally, because the system is web- based, this data would also be available to the individual briefer in order to prepare his or her records for the tank briefings. We propose that by utilizing a web-based system such as our POC and allowing electronic documents to be produced and shared via the network the new system will substantially reduce the time and increase the effectiveness of the promotion process. In order to provide evidence of this, we have created the following sections:

- An "as-is" analysis with a Return on Knowledge (ROK) spreadsheet and graphical representation.
- A "to-be" incremental model spreadsheet.
- Comparison of the "as is" and "to be" models with KVA analysis.
- A fully functional web site that utilizes a notional relational database.
- Prototype web-based charts and graphs using different colors, along with layering and separation multidimensional schemes that would facilitate information flow.

The focus of the chapter will be on the Knowledge Value Added methodology which will provide us with a performance ratio for all the core processes involved in order to determine if there is any increase in effectiveness between the "as-is" and "to-be" models.

B. DATA COLLECTION

Our data collection process focused on obtaining the most suitable information that would provide us with the necessary background to answer the research questions.

Here we will explain how we collected the data. The knowledge assessment - associated with the processes identified during our data collection will identify opportunities for increased returns. The scope of our data collection was limited to the officer promotion process starting from the pre-board stage, beginning with uploading the list of eligible officers, up until the final Tentatively Selected (TS) list is produced. By following the seven steps of the KVA process as listed in Table 1 of chapter 3, we were able to calculate the ROK for the "as is" promotion process.

1. Step One: Identify Core Process and Sub-processes

Our first step was to identify the core process and its sub-processes. In order to establish the boundaries of the core process we needed to describe in detail the "as is" process:

- Identify the end output of the core process.
- Identify the sub-process outputs that eventually create the end product.
- Create and aggregate-level process diagram that depicts the inputs and outputs of the core and each of its sub-processes. Figure 7 is a depiction of our workflow model.

The information that was collected on the "as is" process was gathered through interviews with the subject matter experts (SMEs) involved in the overall process. The SMEs were asked to break the overall process down into smaller, more specific sub-processes through which we could obtain average learning-time estimates and the number of roughly equivalent process instructions required to complete each sub-process. From this data we were able to break up the core promotion process into the following five separate and distinct processes in which to base our "as is" base line model:

- IT Review
- Assistant Recorder Review
- Briefer Review/Annotation
- Data Downloads
- Brief/Presentation/Vote

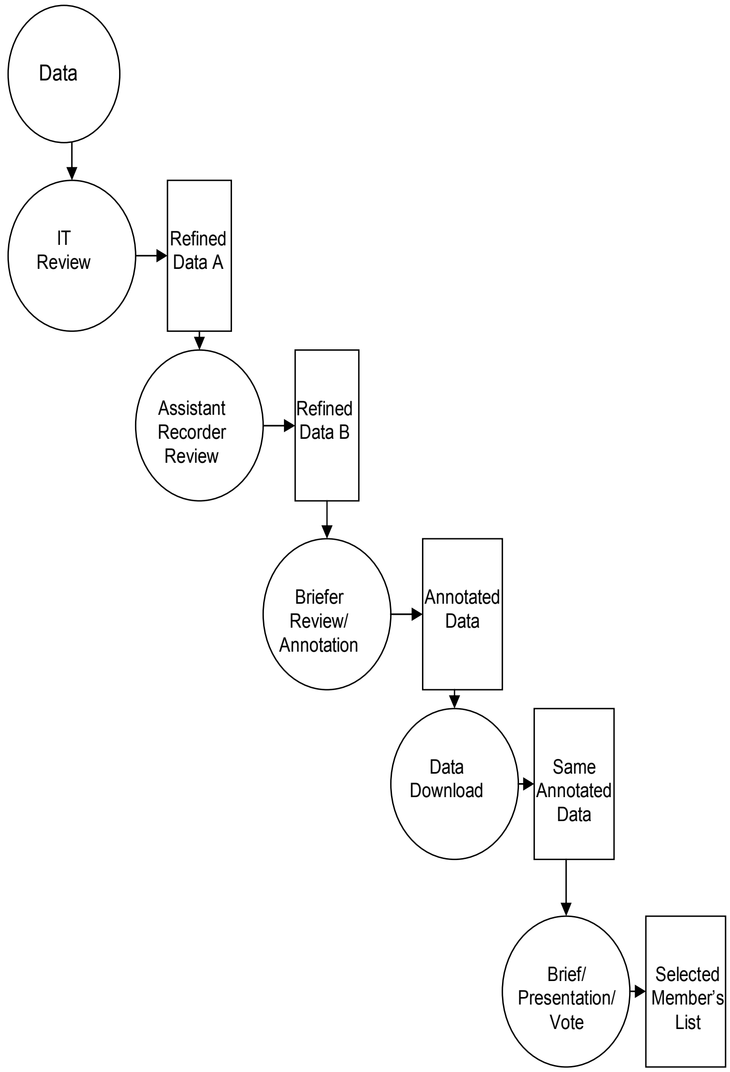


Figure 7. "As Is" Process Model

a. IT Review

The first step in the typical promotion board process starts about four months before the convening date. This is when the initial list of eligible officers is compiled and modified as required. The eligible list is continually synchronized with an official automated database to ensure consideration of all candidates. The master file is queried six weeks prior to the board convening for FITREP continuity and messages are sent for those that are missing. The specific process instructions were identified as:

- Upload list of eligible.
- Perform FITREP continuity check.
- Create a discrepancy database of record with gaps greater than 90 days.
- Post list of web for Fleet access.
- Obtain UICs for command's members missing FITREPS.
- Send messages to Fleet notifying members of gaps in records.
- Log all faxed FITREPS received and check for validity.
- Update website list of missing FITREPS.
- If it's a valid FITREP, then send to the system scanner; if not a valid FITREP, then notify command.
- Prepare board room and tank for use.
- Provide board members and recorders with welcome aboard packages.

b. Assistant Recorder Review

For most boards the recorders arrive one week prior to the board actually being convened. During this week, the assistant recorders are trained in the board's administrative procedures and assigned approximately 80 service records to review. Once proficient, a service record review takes 15 to 20 minutes.

This is the first time that someone other than the eligible will review the record as it will appear before the selection board. The record is reviewed for several items including regular report continuity for the last five years. The OSR/PSR is checked to see that FITREP grades are accurate and the record is reviewed to ensure that award citations are present for the number and type of awards that are listed on the OSR/PSR. The assistant recorder also verifies that an eligible has a photo in current grade.

Any documentation the board receives, either directly from the service member or through the detailer, is logged into the system and scanned into the selection board copy of the service record. Only then can the assistant recorder make the necessary changes on the appropriate Summary Cover Sheet and the PSR. The process instructions involved include:

- Electronically select and open record for review.
- Check that the number of awards in written comments is the same in OSR/PSR page.
- Check that the education in written comments is the same as on the OSR/PSR.
- Check that the grades on FITREPS are the same as on the OSR/PSR.
- Check that photo is current.
- Prepare a list of discrepancies.
- Send messages to member's commands with missing data.
- Accept and enter late data.
- Send to the board members administrative requirements.

c. Briefer Review/Annotation

This sub-process begins once the actual board convenes. Basically, once the board members are checked in, they will receive the administrative and welcome aboard briefs. They will then be briefed on the board precept; a document that is signed by the Secretary of the Navy and is delivered to the board president. It gives guidance on how to conduct the board and is written each time there is a promotion board. The members will then be given a number of records to review, annotate, and grade in preparation for the presentation to the rest of the board. The process instructions include:

- Review Precept letter:
  - selection standard
  - authorized percentage to select
  - cause determination
  - general procedures and schedule
  - equal opportunity guidelines
  - results management guidelines
- Select records for review
- Review and annotate exceptional performance in operational environment, command leadership, integrity, resourcefulness, and innovation.
- Review and annotate graduate education/specialty training.
- Review and annotate clinical proficiency/skill, management skills.
- Review and annotate innovation and retention effectiveness.
- Review and annotate antiterrorism/force protection qualifications.

d. Data Download

After the individual records have been reviewed, annotated, and graded, the reports are then saved to a disk and then separately downloaded into the selection board voting tank module. This procedure often results in a substantial slow down in the

overall process because the information is not immediately available to the voting members in the tank. For example, once enough records have been reviewed and a tank is available (often there is more than one board in session so the tanks may be unavailable) the senior member may decide to go to the tank for the vote. This may be delayed because the reviewed records now have to be separately downloaded into the voting tank module. The sub-process includes:

- Save annotated data file to disk.
- Forward data file for manual download to the board voting tank.

e. Brief/Presentation/Vote

After the records have been downloaded into the tank, all of the voting members gather in the tank where the member who reviewed the record briefs it while the eligible individual's OSR/PSR and cover page are displayed and all board members vote. Sub-process:

- Briefer displays and orally reviews annotated data.
- All members compare with experience baseline for:
  - Exceptional performance in operational environment, command leadership, integrity, resourcefulness, and innovation
  - Graduate education/specialty training
  - Clinical proficiency/skill, management skills
  - Innovation and retention effectiveness
  - Anti-terrorism/force protection qualifications
- All members cognitively "normalize" graded averages and the R.S.'s cumulative average.
- All members cast vote for each record, cognitively normalizing all data with regard to all eligible records.

2. Step two: Establish Common Units to Measure Learning Time

In step two, we were able to establish, through our interviews with the SMEs, a common definition of learning time (LT) for the five processes under review. LT is the amount of time it takes for an average person to learn how to complete the process correctly and is directly correlated to the amount of knowledge embedded in a given process.

3. Step three: Calculate Learning Time to Execute each Sub-process

With the SMEs input, we were able to determine the total time it would take to learn how to execute each sub-process. Given that there were an estimated total of 100

weeks to learn how to execute the five processes; the distribution of learning time is depicted in Table 5 below.

Process:	**Learning time (months)**
Data Download	1
IT Review	6
Assistant Recorder Review	8
Briefer Review/Annotation	41
Brief/Presentation/Vote	44
Total	100

Table 5 Actual Learning Times

4. Step four: Designate Sampling Time Period

In step four, instead of designating a sampling time period in order to capture a representative sample of the compound processes' final output, we used the number of employees within each core area to determine the weighted amount of knowledge executed in the process per 1000 records. The "Persons involved" category reflects the number of people involved in completing a process. Accounting for the number of employees gives a general idea of how often knowledge (K) is fired and provides a rough-cut way of weighting knowledge in the processes over the evaluation period (Housel and Bell, 2001). See Table 6.

	Value added (hours to train)	**Persons involved (weighting factor)**	**Time subtotal**
Data Download	.2	1	.2
IT Review	.5	3	1.5
Assistant Recorder Review	.8	7	5.6
Briefer Review/Annotation	3	1	3
Brief /presentation/Vote	5	11	55
Totals:	9.5	23	65.3

Table 6 Step 4: Weighting factor

5. Step five: Multiply the Learning Time for each Sub-Process

In this case we took the time subtotal and multiplied it by the number of times the knowledge for that particular sub-process was fired or actually used. The number of times fired is a close approximation from the SME in that field of how many times per 1000 records that the requisite knowledge for that process was actually used. We then

used that subtotal and multiplied it by the estimated number of iterations of the sub-process to be executed during a board for each 1000 records. The result is the weighted value which is ultimately used as the top half of the return ratio. In other words, the sum of the total amount of learning time knowledge for each process is used as the numerator in the ROK equation. It is the knowledge required to get the outputs. See Table 7 below.

	Time Subtotal	**X # of times fired**	**Fired subtotal**	**X # of iterations**	**= Weighted Value Added**
Data Download	.2	1	.2	6	1.2
IT Review	1.5	1	1.5	1	1.5
Assistant/Recorder	5.6	143	800.8	1	800.8
Brief Review	3	83	249	2	498
Brief//presentation	55	1000	55000	2	111000
Total:	65.3				111301.5

Table 7 Step 5 of the KVA Calculation

6. Step 6: Allocate Revenue

In step six we calculate the cost to execute each sub-process based solely on the cost of the personnel at each sub-process. Rather than trying to figure out the different TAD (Temporary Additional Duty) costs for each rank, which is too complex, we chose to normalize the cost data in the following way. If the process used two E-5 personnel then we estimated how long in hours it took to complete the process step and then determined the cost based on the average time of service of a typical E-5 in the Navy. For example, an E-5 over six years of service gets paid X dollars per month divided by 80 hours per month. We then determined that if the process step took eight man-hours then eight man-hours times the hourly rate equals the total sub-process cost. Here we attempted to isolate just those costs that pertain to the creation of the process outputs. The estimates were based on the SMEs approximations on how long it took individuals to generate the outputs necessary to complete a specific task. For example, referring to table xxx, we estimated that for every 1000 records reviewed, six separate data downloads were required on average, based on 160 records reviewed before being sent to the tank. We estimated that each download would take about 1 hour for a total execution time for that process of six hours per 1000 records reviewed. See Table 8.

	Execution time (hours)	Process Costs ($)
Data Download	6	$40.70
IT Review	72	$366.30
Assistant/Recorder	280	$1852.80
Brief Review	360	$27,633.59
Brief//presentation	120	$29,655.56
Total:		$59,548.95

Table 8 Step 6 of the KVA Calculation

7. Step 7: Calculate ROK and Interpret the Results

In the last step we computed the ROK for each sub-process by taking the weighted value added for each sub-process and dividing it by the process costs. By breaking the ROK figures down to the individual processes, we are then able to generate an order of magnitude estimate of the return, based solely on the ratio of cost to amount of knowledge and process instructions executed during the sample period. The overall ROK for all of the processes in the "as is" model is 186.91%. See Table 9.

= Weighted Value Added	Process Instructions (uwt)	Execution time (hours)	Process Costs ($)	ROK*** (%)
1.2	2	6	$40.70	2.95%
1.5	11	72	$366.30	0.41%
800.8	9	280	$1,852.80	43.22%
498	13	360	$27,633.59	1.80%
110000	48	120	$29,655.56	370.93%
111301.5	83		$59,548.95	186.91%

Table 9 ROK Calculations

VISUALIZATION
SELECTION BOARD PROCESS
(PER 1000 RECORDS)

Sub Process	Learning time (months)	Value added (hours to train*)	Persons Involved	Time Subtotal	X # of Times Fired*	Fired Subtotal	X # of Interations	= Weighted Value Added	Process Instructions (uwt)	Execution time (hours)	Process Costs ($)	ROK*** (%)
Data Download	1	0.2	1	0.2	1	0.2	6	1.2	2	6	$40.70	2.95%
IT Review	6	0.5	3	1.5	1	1.5	1	1.5	11	72	$366.30	0.41%
Assistant Recorder Review	8	0.8	7	5.6	143	800.8	1	800.8	9	280	$1,852.80	43.22%
Briefer Review/Annotation	41	3	1	3	83	249	2	498	13	360	$27,633.59	1.80%
Brief/Presentation/Vote	44	5	11	55	1000	55000	2	110000	48	120	$29,655.56	370.93%
Totals	100	9.5	23	65.3				111301.5	83		$59,548.95	186.91%

Correlations	
Hours to train correlated to Learning time in months	Hours to train correlated to Process Instructions
0.955	0.907

*total of each sub process instruction x portions of hours to train

**frequency of fire is same as # of widgets produced

***ROK: Weighted Value Added/ Process Costs

Table 10 Overall "as is" KVA Analysis

C. "TO BE" INCREMENTAL DESIGN KVA ANALYSIS

With the base-line model we created, we produced our incremental "to-be" model and compared the two for any differences in the ROK figures. Additionally, this base line model can be used to compare any future re-design efforts, including a radical redesign of the process such as using the five vector model for the purposes of promotions. As explained previously, our "to-be" incremental design is envisioned to be web-based and thus introducing advanced automation and accessibility options into the process. A major benefit we foresee is eliminating redundant or repetitive sub-processes such as the data download stage prior to each tank session. Figure 8 shows the redesigned or incremental process model.

There is one major difference between the "to-be" and "as-is" model. In the "to-be" model, we completely eliminated the sub-process for the data being manually downloaded to the tank. Although this has only really eliminated two process instructions, we show in our spreadsheet analysis that this equates to a significant time reduction in the overall process.

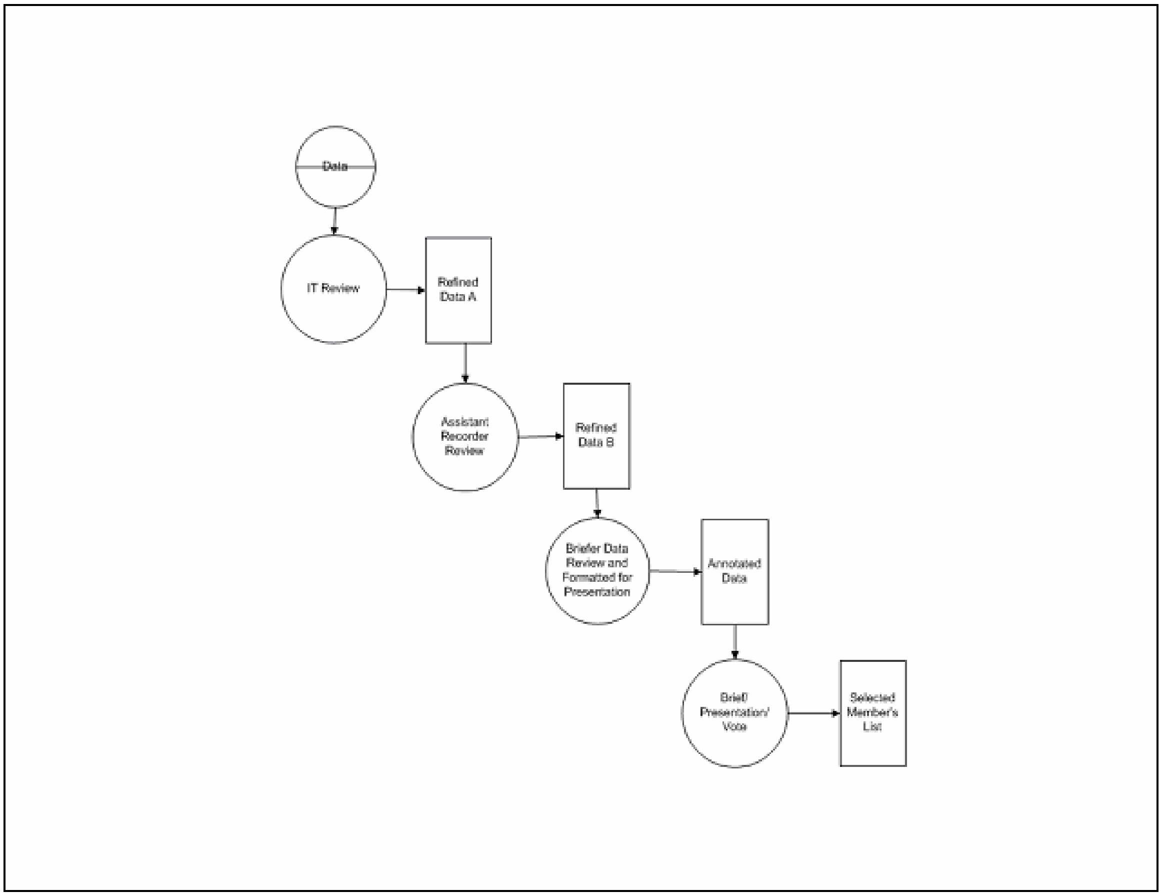


Figure 8. "To-be" incremental process flow diagram

The following is a list of the "to-be" sub-processes with their respective process instructions:

- IT Review
  - Process instructions remain the same as the "to–be" model.
- Assistant Recorder Review
  - Process instructions remain the same
- Briefer Data Review and Formatted for Presentation
  - Process instructions remain the same
- Brief Presentation/Vote
  - Briefer displays and orally reviews annotated data.
  - All members visually compare record with peer performance aggregate baseline data.
  - All members cast vote for each record.

For the scope of our POC model, the sub-processes and process instructions for the incremental design are essentially the same as the "as-is" model until after the Briefer Review/Annotation sub-process. However, with the current work being done through the

Navy's personnel and manpower modernization effort, it is possible for all of the sub-process to be significantly reduced, thus allowing for much higher ROK figures in the future. For the scope of this project however, we have decided to limit the re-design to only those sub-processes that would be directly affected by our POC model. The following table (Table 11) lists the specific numerical difference in the ROK analysis for the "to-be" model:

VISUALIZATION - INCREMENTAL
SELECTION BOARD PROCESS
(PER 1000 RECORDS)

Learning time (months)	Value added (hours to train*)	Persons Involved	Time Subtotal	X # of Times Fired*	Fired Subtotal	X # of Interations	= Weighted Value Added	Process Instructions (uwt)	Execution time (hours)	Hourly rate ($)	Process Costs ($)	ROK*** (%)
4	0.2	1	0.2	1	0.2	6	1.2	2	6	$6.78	$40.68	2.95%
6	0.5	3	1.5	1	1.5	1	1.5	11	72	$5.09	$366.48	0.41%
11	0.8	7	5.6	143	800.8	1	800.8	9	280	$6.62	$1,853.60	43.20%
35	3	1	3	83	249	2	498	13	240	$76.76	$18,422.40	2.70%
44	5	11	55	1000	55000	2	110000	48	60	$247.13	$14,827.80	741.85%
100	9.5	23	65.3				111301.5	83			$35,510.96	313.43%
						Hours to train correlated to Learning time in months	Hours to train correlated to Process Instructions					
						0.984	0.907					

Table 11 Overall "to-be" KVA analysis

D. COMPARATIVE ANALYSIS

The KVA methodology offers a means in which to objectively measure the value of knowledge assets deployed in core processes. The value measurement of knowledge embedded in an organization's core processes, technology, and employees is accomplished by determining what the organization's Return on Knowledge (ROK) is. The numerator of the ratio represents the percentage of the revenue or sales dollar allocated to the amount of knowledge required to complete a given process successfully, in proportion to the total amount of knowledge required to generate the organization's total outputs. The denominator of the ratio is the cost to execute the process knowledge. By comparing the "as-is" figure in Table 12 to the "to-be" model in Table 13, we see a significant difference in the ROK figures. The "to-be" model is a close approximation of the redesigned web-enabled promotion process to include the enhanced OSR/PSR graphical display.

Process Instructions (uwt)	Execution time (hours)	Process Costs ($)	ROK*** (%)
2	6	$40.70	2.95%
11	72	$366.30	0.41%
9	280	$1,852.80	43.22%
13	360	$27,633.59	1.80%
48	120	$29,655.56	370.93%
83		$59,548.95	186.91%

Table 12 “As-is” ROK figures

Process Instructions (uwt)	Execution time (hours)	Process Costs ($)	ROK*** (%)
2	6	$40.68	2.95%
11	72	$366.48	0.41%
9	280	$1,853.60	43.20%
13	240	$18,422.40	2.70%
48	60	$14,827.80	741.85%
83		$35,510.96	313.43%

Table 13 “To-be” ROK figures

As evident from the figures, the ROK does not significantly change until we change the later sub-processes of Briefer Review and the Brief/Presentation/Vote. In the last case we can see that with the new process, the ROK in last sub-process has doubled from 370.93 percent to 741.85 percent. In other words, the amount of knowledge executed during that time frame (knowledge is a surrogate for the process outputs measured in common units) is significantly higher in the Brief/Presentation/Vote sub-process with the “to-be” incremental design.

Does the overall increase in ROK from 186.91 percent to 313.43 percent support our principle research questions?

- Can data-information visualization best practices be embedded in information technology in order to improve the overall effectiveness and objectiveness of the selection board process?
- Will integrating web-based technology with the visualization techniques reduce the time required to prepare, brief, and make decisions in the promotion process?

These questions are really about improving the effectiveness and efficiency of the decision making process. *Effectiveness* in decision making is focused on *what* should be done, whereas *efficiency* is focused on *how* we should do it. George M. Marakas, in his book *Decision Support Systems in the 21st Century*, explains the difference between the two in the context of how a decision support system contributes to each:

Effectiveness

- Easier access to relevant information.
- Faster and more efficient problem recognition and identification.
- Easier access to computing tools and proven model to compute choice criteria.
- Greater ability to generate and evaluate large choice sets.

Efficiency

- Reduction in decision costs.
- Reduction in decision time for same level of detail in the analysis.
- Better quality in feedback supplied to the decision maker.

By strictly comparing the KVA ROK figures of the before and after processes, we can easily see that the second question regarding efficiency has been improved. By using a fully web-enabled system, it would reduce process instructions involved in the later sub-processes which would result in an overall more efficient process. Further, we can surmise that by using our approach, the execution time in hours would decrease from 360 hours in the Briefer Review/Annotation phase to 240 hours for every 1000 records. The big difference, however, was reducing execution time in the Brief/Presentation/Vote phase from 120 hours to 60 hours. This one improvement resulted in the dramatic increase in ROK. We believe that the data visualization techniques would help shorten the process instruction involved in the "voting" process due to its powerful ability to convert data objects into information so quickly.

In the next chapter we will introduce our POC prototype web site that will shows how we can further increase the effectiveness by having;

- easier access to relevant information
- faster and more efficient problem recognition and identification
- easier access to computing tools and proven models to compute choice criteria
- provide a greater ability to generate and evaluate large choice sets

V. VISUAL ONLINE PROMOTIONS SYSTEM (VOPS)

A. OVERVIEW

In this chapter, we will explain the Visual Online Promotions System (VOPS), the system we developed to address the thesis objectives. We begin by explaining the different security approaches we considered and describe the construction of our information technology solution. The prototype helps the reader understand our redesign vision and supports the research questions of this thesis.

B. SECURITY APPROACH

The current promotion system consists of the Electronic Military Personnel Records Management System (EMPRS) that encompasses the Primary Input/Output system (PRIO), the Fitness Report/Evaluation system (FITEV), and Selection Board Module (SELBD). These modules work together to create a system that allows operators to manage member records from the desktop. All these systems are internal, meaning they can only be accessed via the interfaces at the Navy Personnel Command in Millington Tennessee. The advantages to this approach include increased security and local administration of the intricate information systems.

The prototype we designed is intended to provide access through the Internet, using encryption and password protected access. The advantages to having the system accessible from anywhere a person has Internet connectivity benefits not only the board members, who in the future will have the ability to peruse records from their own station, but also the promotion candidate who can access the system and see what information about him or her is available, current, and seen by the board. This web-enabled concept introduces another layer of security concerns and requirements beyond the scope of this thesis but we designed our system assuming these technical and procedural concerns will be researched and implemented separately.

The Visual Online Promotions System (VOPS) may be implemented using either a closed intranet or public Internet approach, but we designed our prototype to simulate access via the Internet because we believe that future implementations will eventually use a web-enabled, virtual board system using some form of collaborative technology.

C. WEB APPLICATION PROTOTYPE DEVELOPMENT

To construct the VOPS, we used a variety of software components. Specifically, Table 14 identifies and describes the purpose of each software component.

Maker	Software Title	Version	Purpose
Macromedia	Dreamweaver MX	6.0	Design and draft static HTML pages and dynamic ASP pages
Microsoft	Access	XP	Create a database containing the promotion data
Microsoft	Internet Explorer	6.0	View completed web pages and test application
Microsoft	Internet Information Server	6.0	Localized server software to enable Dreamweaver to display dynamic web pages (connects web page, database, and browser)

Table 14 Software solutions used to develop VOPS prototype

1. Overview of 3-Tier Architecture

While the scope of this thesis is focused on streamlining the Naval promotion system using a notional solution, the actual solution will likely involve some form of 3-tier architecture so we believe a concept overview is warranted.

For web applications such as what we are proposing, a 3-tier architecture is currently the best solution. It consists of a client tier, or presentation layer, where the user sees the information. The second tier is the application tier, or business-rule layer, and protects the data from direct access by the clients. The third tier, or data layer, is simply where the data is stored and is accessed via the application layer. The first two tiers are normally housed within the client's machine with the data layer accessed through a network.

Because the 3-tier architecture protects the data and provides a robust design, creating the VOPS using this popular and powerful architecture scheme provided the best solution for our design.

Using the software tools in Table 14, we set out to design the VOPS with a database, static web pages, and dynamic web pages using the Active Server Page (ASP) technology. By creating a notional Access database and designing web pages that dynamically query the data, we were able to implement a rapid prototype as a Proof Of Concept (POC).

2. The Notional Database

We designed a Microsoft Access database to house the VOPS data that we would query from the web pages. Figure 9 shows the schema we designed to normalize the data and to provide the necessary query capabilities to query a variety of data.

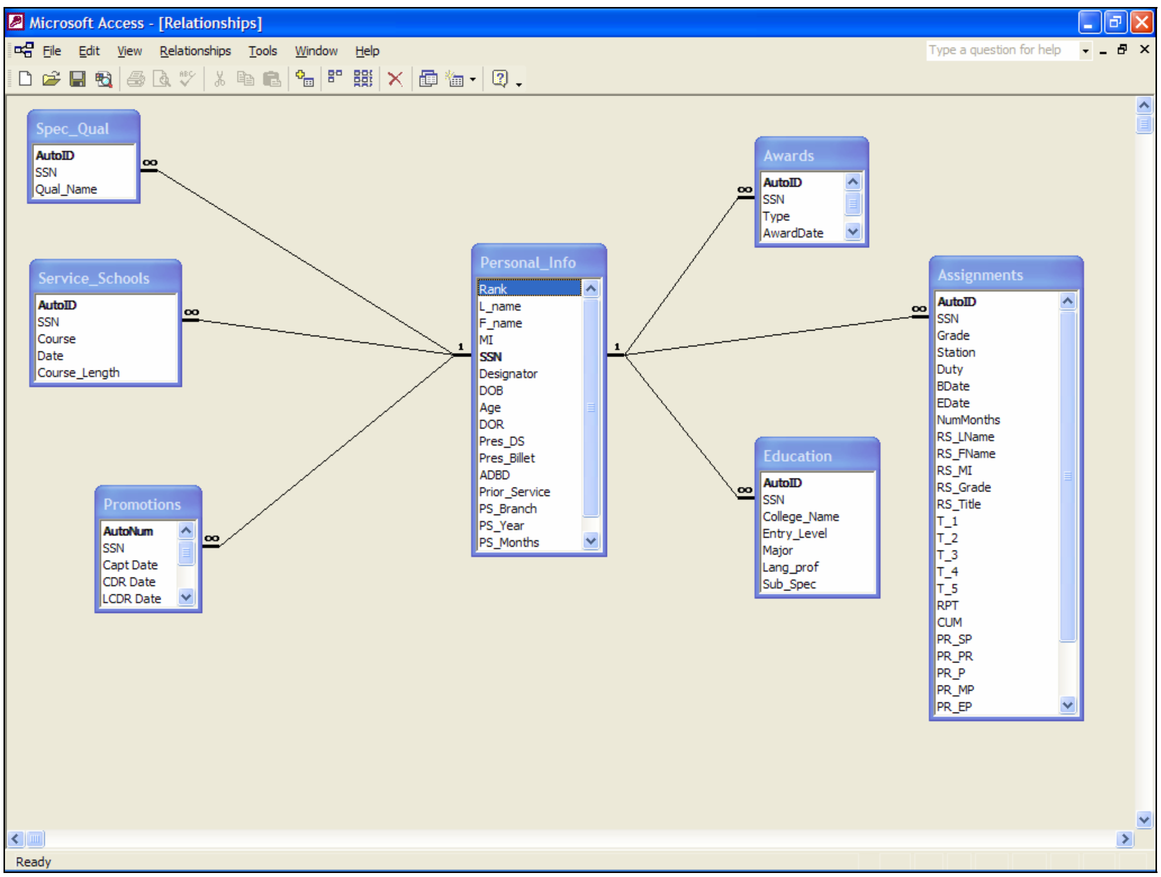
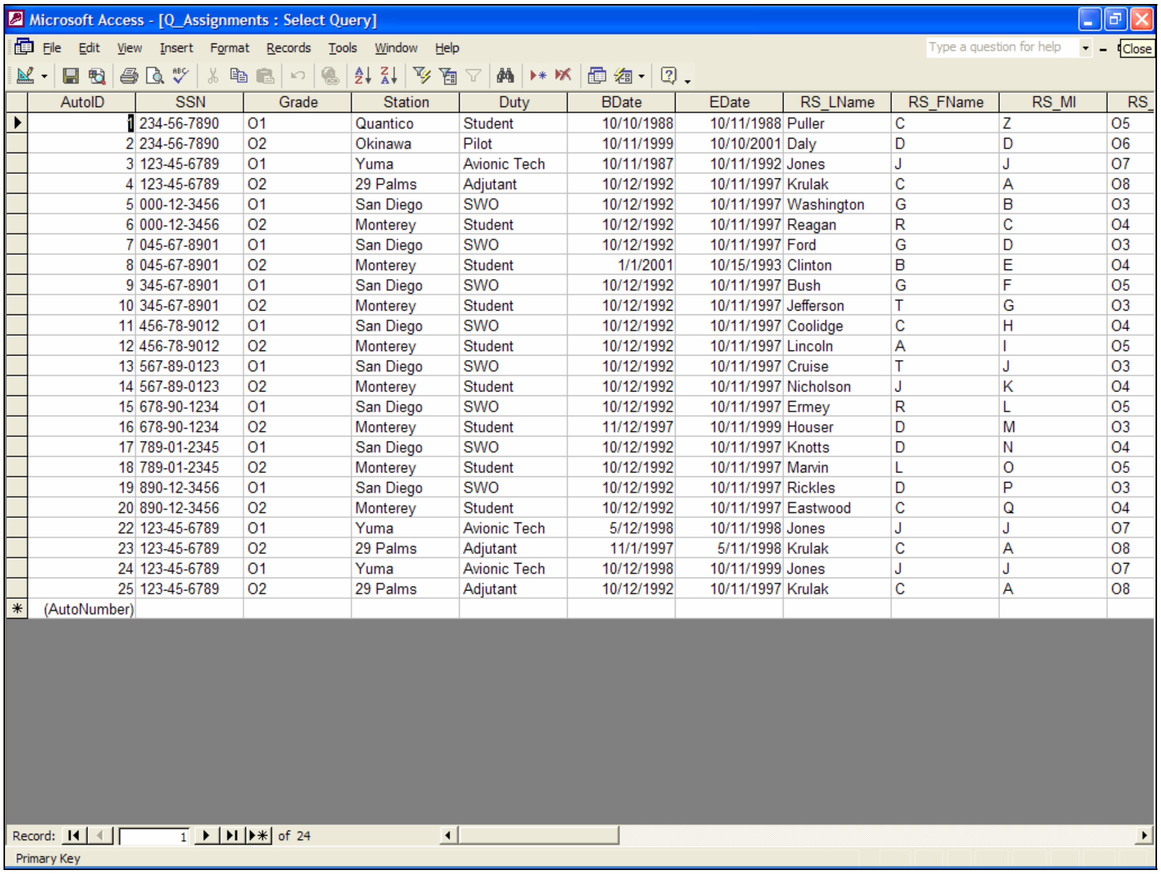


Figure 9. Schema of the VOPS's Notional Database

Each block represents a table of information and the adjoining lines are relationships between the tables, hence a "relational" database. By isolating the data in this way, updates and maintenance can be accomplished cleanly without the problems associated with having redundant information in different locations.

It is important to note that the tables are never directly accessed but only via a set of queries designed to provide subsets of the data for the requested information, as seen in Figure 10. Note also that horizontal rows contain a record, or collection of data on one person. The vertical columns are the individual data fields for each record. Both queries and tables are organized in this manner.



AutoID	SSN	Grade	Station	Duty	BDate	EDate	RS_LName	RS_FName	RS_MI	RS
1	234-56-7890	O1	Quantico	Student	10/10/1988	10/11/1988	Puller	C	Z	O5
2	234-56-7890	O2	Okinawa	Pilot	10/11/1999	10/10/2001	Daly	D	D	O6
3	123-45-6789	O1	Yuma	Avionic Tech	10/11/1987	10/11/1992	Jones	J	J	O7
4	123-45-6789	O2	29 Palms	Adjutant	10/12/1992	10/11/1997	Krulak	C	A	O8
5	000-12-3456	O1	San Diego	SWO	10/12/1992	10/11/1997	Washington	G	B	O3
6	000-12-3456	O2	Monterey	Student	10/12/1992	10/11/1997	Reagan	R	C	O4
7	045-67-8901	O1	San Diego	SWO	10/12/1992	10/11/1997	Ford	G	D	O3
8	045-67-8901	O2	Monterey	Student	1/1/2001	10/15/1993	Clinton	B	E	O4
9	345-67-8901	O1	San Diego	SWO	10/12/1992	10/11/1997	Bush	G	F	O5
10	345-67-8901	O2	Monterey	Student	10/12/1992	10/11/1997	Jefferson	T	G	O3
11	456-78-9012	O1	San Diego	SWO	10/12/1992	10/11/1997	Coolidge	C	H	O4
12	456-78-9012	O2	Monterey	Student	10/12/1992	10/11/1997	Lincoln	A	I	O5
13	567-89-0123	O1	San Diego	SWO	10/12/1992	10/11/1997	Cruise	T	J	O3
14	567-89-0123	O2	Monterey	Student	10/12/1992	10/11/1997	Nicholson	J	K	O4
15	678-90-1234	O1	San Diego	SWO	10/12/1992	10/11/1997	Ermey	R	L	O5
16	678-90-1234	O2	Monterey	Student	11/12/1997	10/11/1999	Houser	D	M	O3
17	789-01-2345	O1	San Diego	SWO	10/12/1992	10/11/1997	Knotts	D	N	O4
18	789-01-2345	O2	Monterey	Student	10/12/1992	10/11/1997	Marvin	L	O	O5
19	890-12-3456	O1	San Diego	SWO	10/12/1992	10/11/1997	Rickles	D	P	O3
20	890-12-3456	O2	Monterey	Student	10/12/1992	10/11/1997	Eastwood	C	Q	O4
22	123-45-6789	O1	Yuma	Avionic Tech	5/12/1998	10/11/1998	Jones	J	J	O7
23	123-45-6789	O2	29 Palms	Adjutant	11/1/1997	5/11/1998	Krulak	C	A	O8
24	123-45-6789	O1	Yuma	Avionic Tech	10/12/1998	10/11/1999	Jones	J	J	O7
25	123-45-6789	O2	29 Palms	Adjutant	10/12/1992	10/11/1997	Krulak	C	A	O8
(AutoNumber)										

Figure 10. The Assignments Query

We understand that Microsoft Access, while a powerful prototyping tool, is not scalable for enterprise-level solutions and therefore the actual operational VOPS would require a more robust database. Nevertheless, the concepts are the same. The data will be stored in a database and accessed by the design architecture's middle tier on its way to the presentation layer. For this reason, we will not delve too deeply into the mechanics of Access or the notional database we created.

D. THE VOPS PROTOTYPE

Our original intent for the VOPS prototype was to mimic the actual Naval Personal Command's web site design and navigation to the point where we introduce our new procedures. To that end, we designed our pages as a scaled down version of the actual Personal Command's web site.

On the BUPERS homepage (Figure 11), a link takes a user to the Selection Board page where all active boards are listed and hyperlinks take the user to the particular board he or she is interested in. (Figure 12).

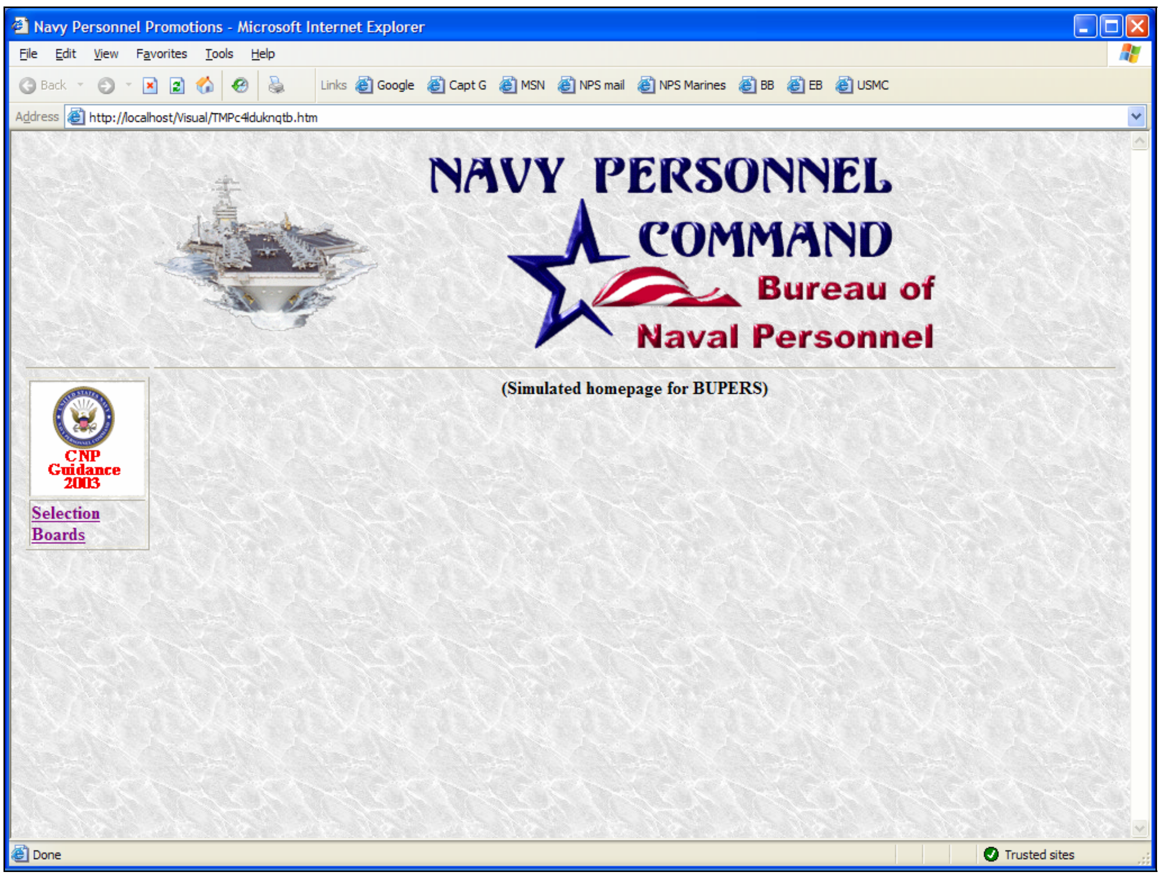


Figure 11. Simulated homepage for BUPERS

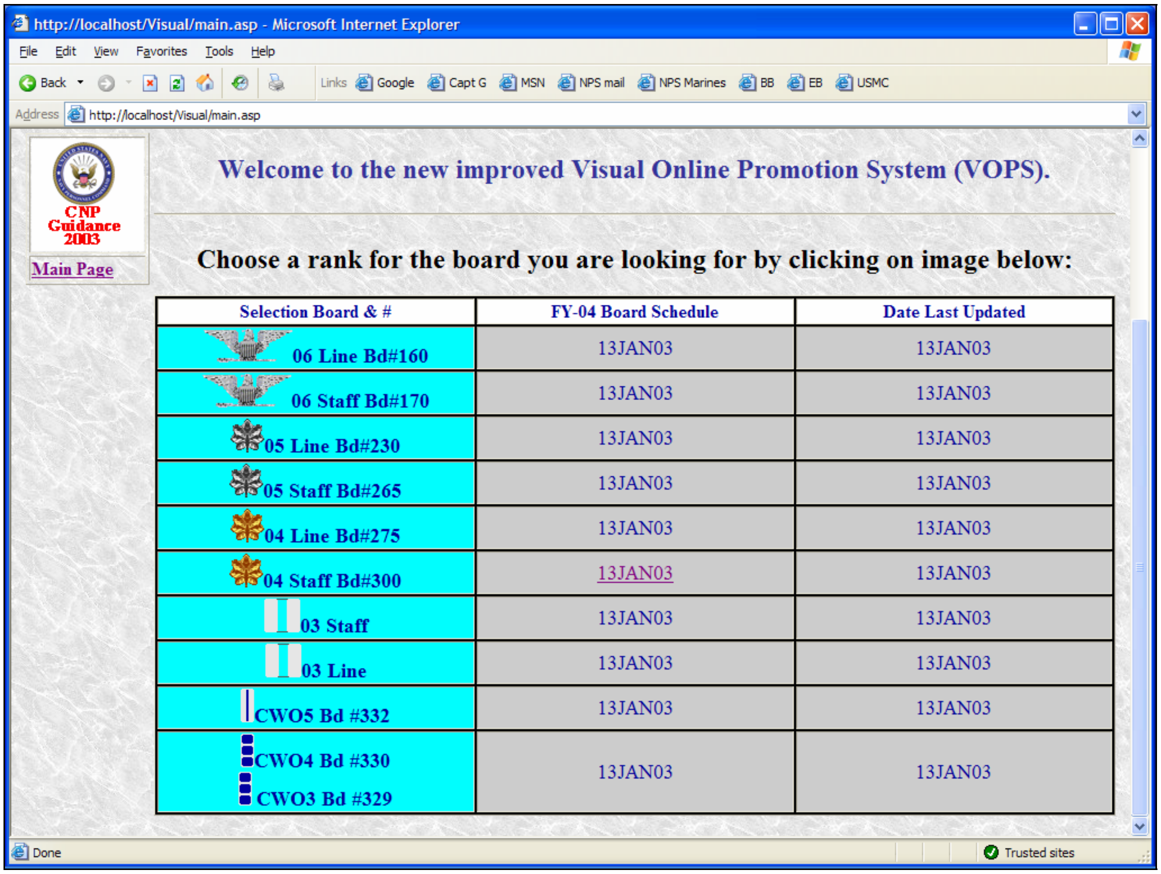


Figure 12. Selection Board Display Page

While all current boards are listed, only boards that have information will have links. The purple link in figure 12 indicates a followed link which takes the user to Figure 13.

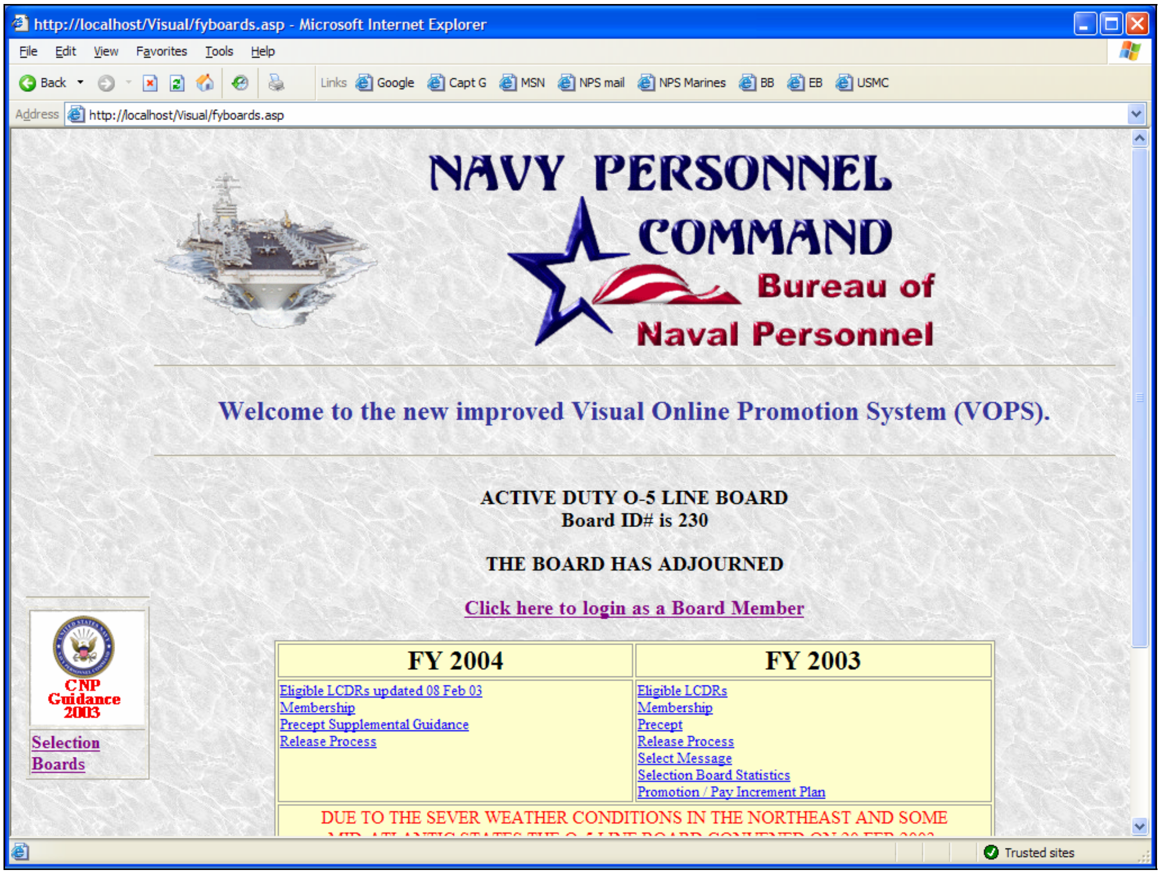


Figure 13. Individual Board Display Page

So far, we have not introduced any changes to the current website. In our prototype, anyone can access the pages we have seen thus far; it is only at Figure 13 that we branch off to provide dual capability for the candidate and the board member.

In Figure 13, a board member can access the promotion board pages by clicking on the "Click here to login as a board member" link which will take him or her to Figure 14. Regardless of the security approach adopted, this log in page will provide a level of security to the process necessary to protect the promotion selection process.

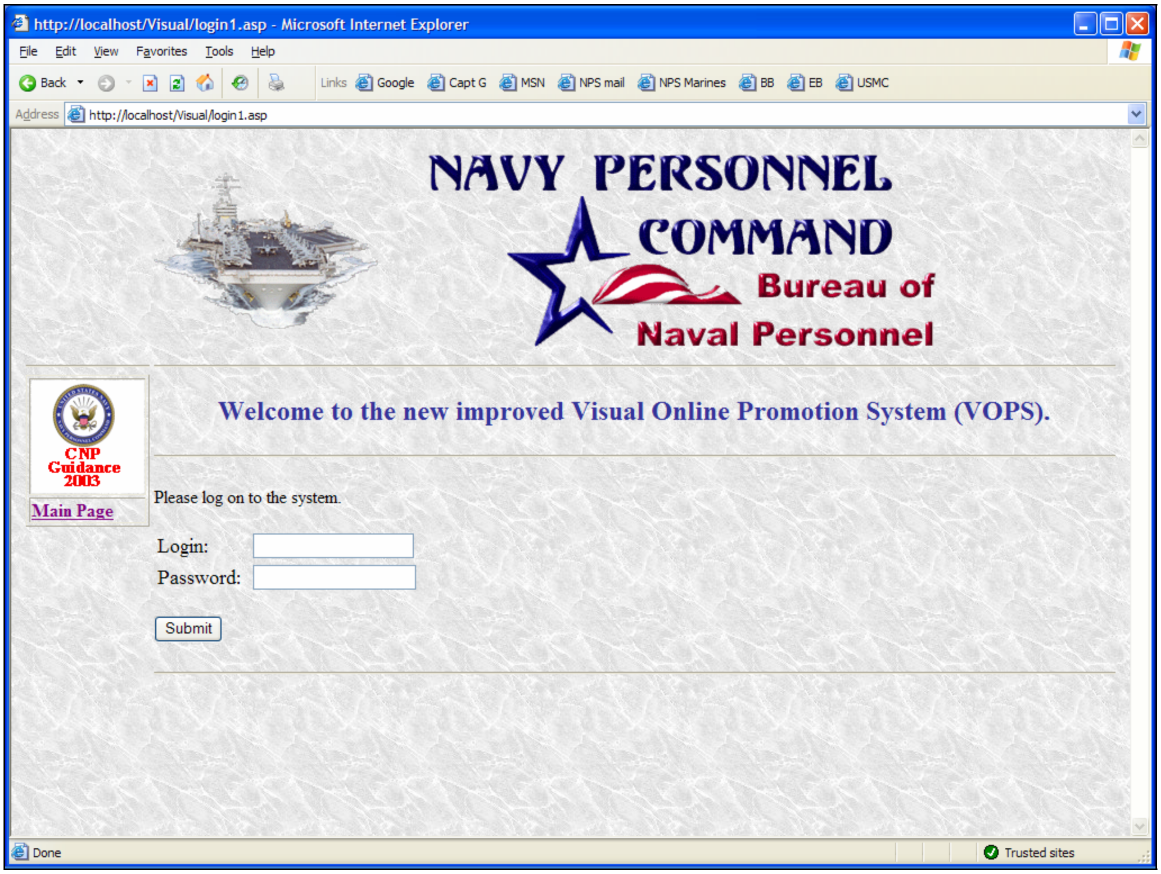


Figure 14. VOPS Board Member Log In Screen

Once the user has been identified and verified, the system displays only the records he or she is assigned (Figure 15). The list of candidates will differ from board member to board member depending on the individual records assigned to each. With the click of a link, the board member has access to each candidate's Officer Summary Record (OSR, Figure 16) Cover Page and Performance Summary Record (PSR, Figure 17) which are both dynamic, web-enabled versions of the documents currently used to display the candidate's history. We believe that providing a layout similar to what has been traditionally provided was necessary for procedural continuity so that the board members can access detailed information for their pre-tank record review.

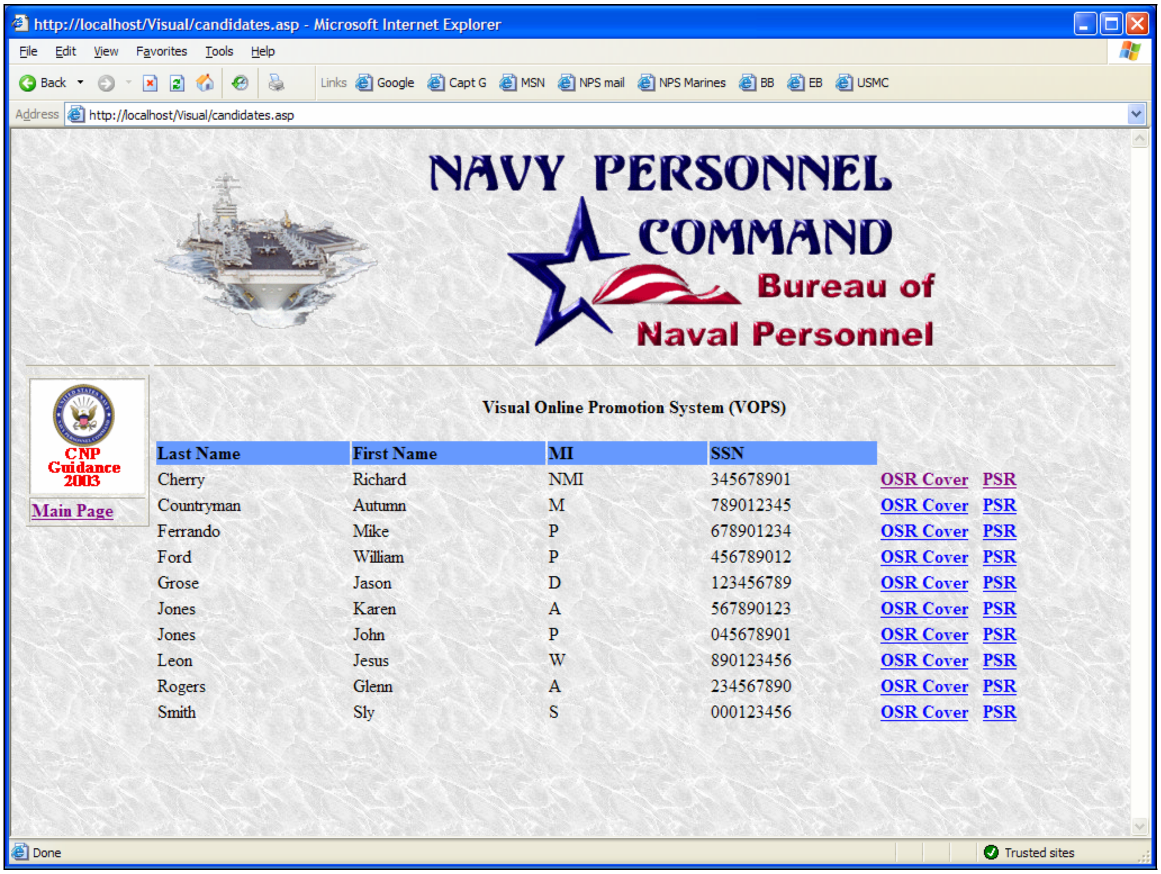


Figure 15. Candidate Record Display for Individual Board Member

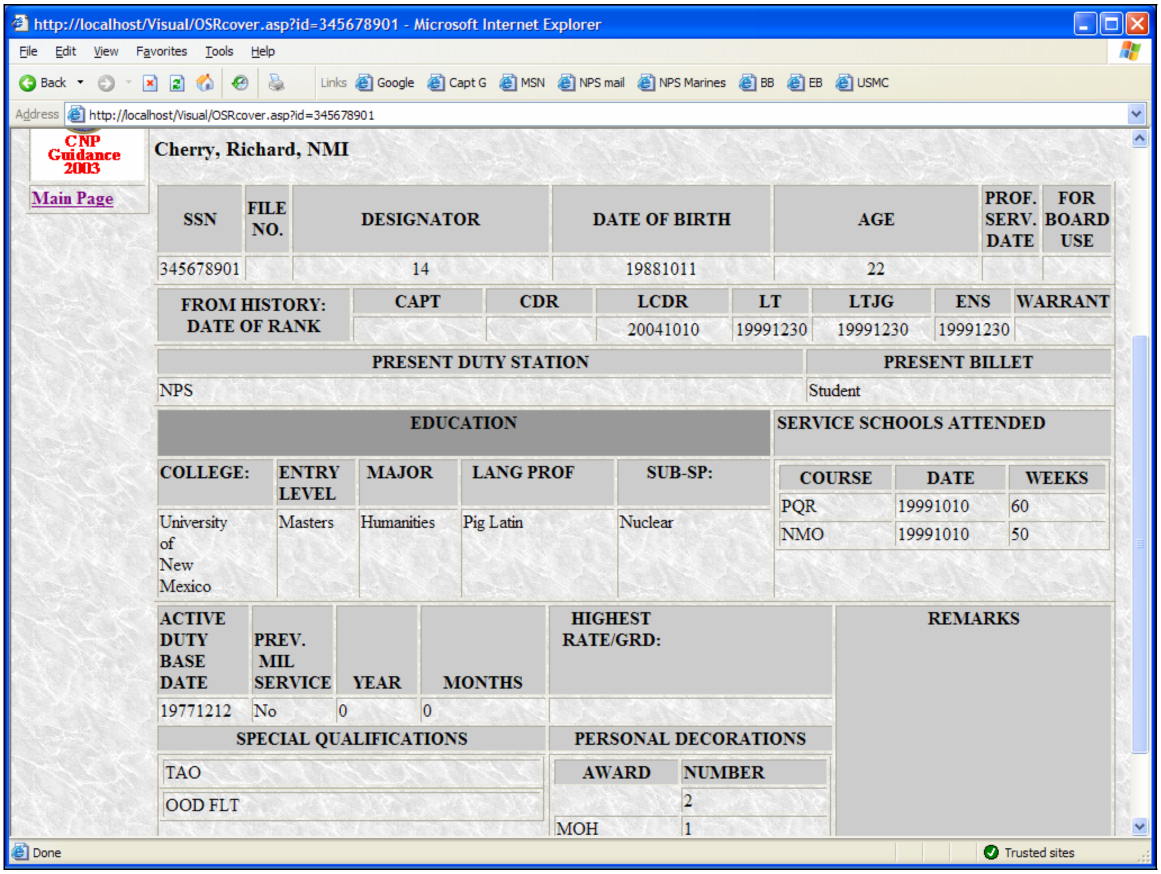


Figure 16. VOPS OSR Cover Page

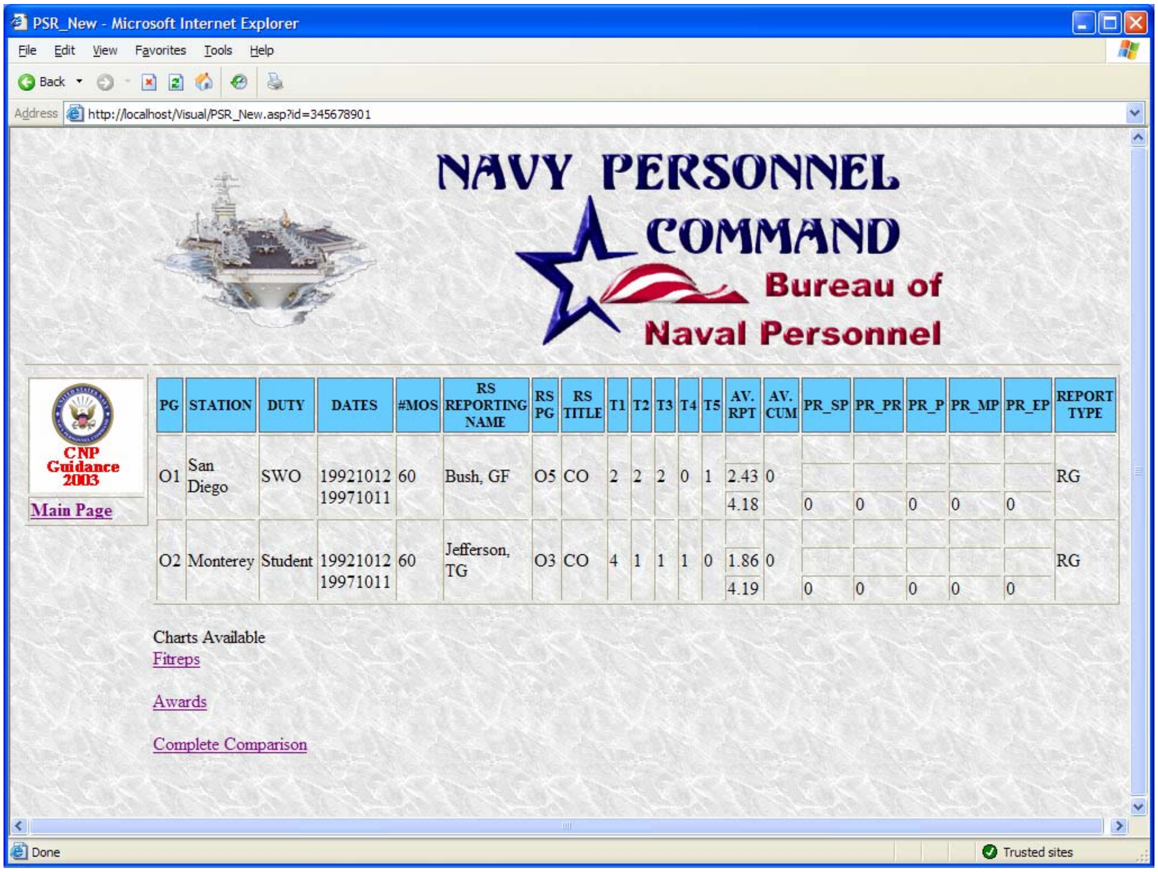


Figure 17. VOPS PSR Page

After clicking on the "Fitreps" link in Figure 17, the user is taken to a dynamic page that displays summary performance marks for the candidate in the same manner the tank currently sees the information. Because the reviewer's needs differ slightly from the tank needs, this traditional view of information is necessary for the reviewer. Because the tank members benefit from summary, graphical information rather than raw data, we redesigned the fitness report data to take advantage of the visual techniques discussed in chapter III (Figure 18).

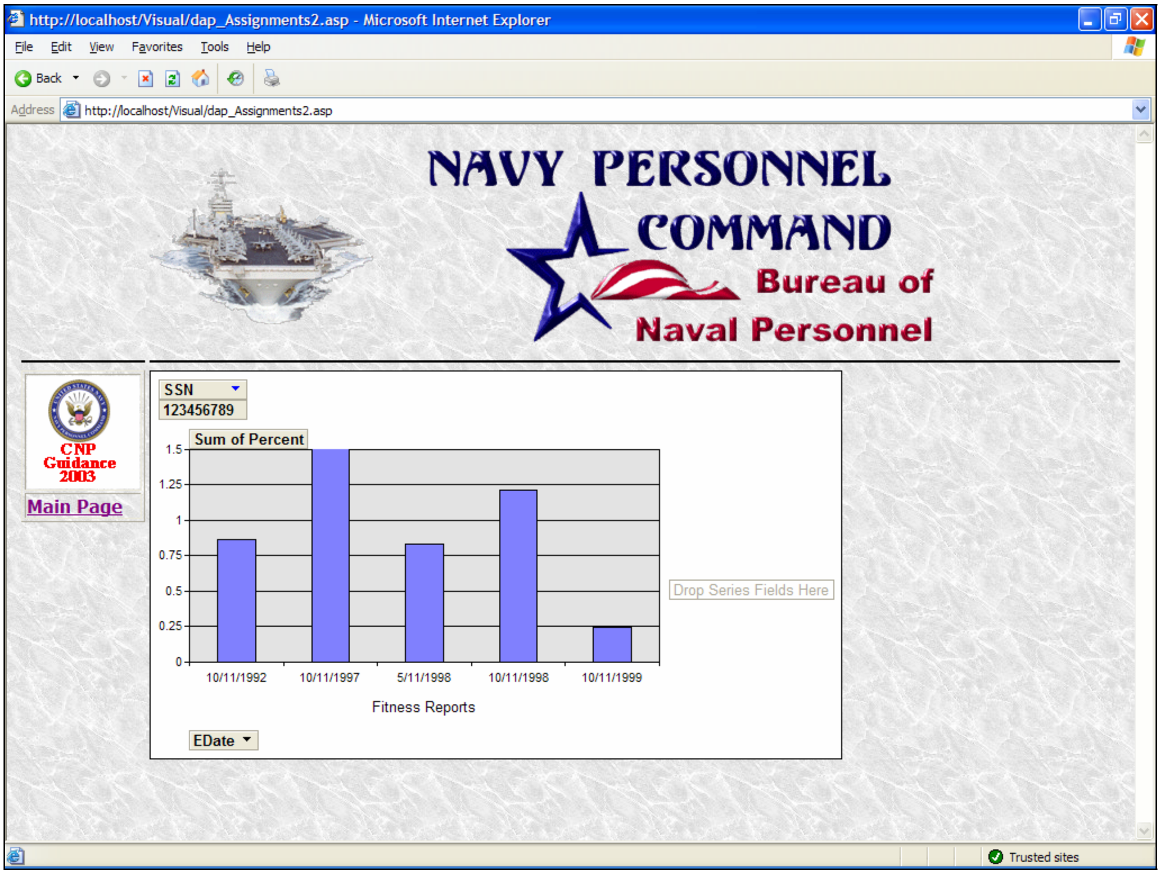


Figure 18. Dynamic Fitness Report Overview Graph

In our design, the data is normalized so that a reporting senior's (RS) grading behavior is neutralized. For example, if a candidate performs extremely well at his first duty station, but because his reporting senior tends to grade everyone toward the bottom of the performance scale, the candidate might receive a grade of 3.0 which is above average for that reporting senior. At his next command, the candidate might do very poorly but the reporting senior grades high with a result of a 4.0 which translates to a below average mark from that particular reporting senior. Looking at these two grades without normalizing, a board member will interpret that the candidate performed poorly at his first command and better at his second command: exactly the opposite of the reality.

For this reason, we normalized the data, taking into account the grading history of each reporting senior. In Figure 18, a grade of 1.0 is the exact average of the reporting senior so anything above that line indicates superior performance, and where anything below 1.0 indicates poor performance, relative to the reporting senior grading criteria. In

the design of these graphics, we tried to incorporate the important principles of graphical integrity as spelled out in chapter three. "Graphics must not quote data out of context … the representation of numbers, as physically measured on the surface of the graphic itself, should be directly proportional to the numerical quantities represented" (Tufte, 2001).

Similar to the fitness report display, we designed a page that dynamically pulls award information and displays it to the reviewer. Figure 19 is an example of the new awards page and shows the board members at a glance not only the awards the candidate received, but the relative importance of each award, indicated by the height of the bar: the higher the award precedence, the taller the bar. In this way, the board spends less time correlating the different awards and can see when each award was earned.

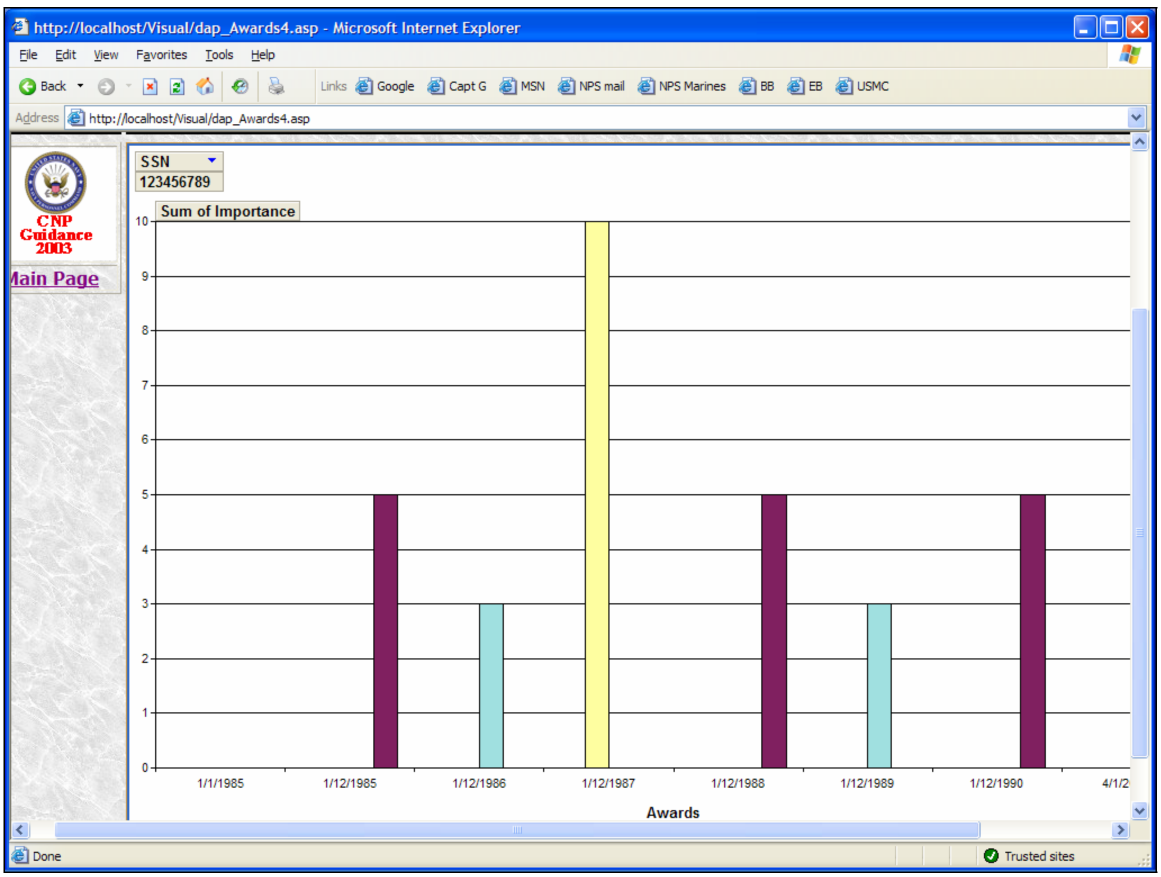


Figure 19. Dynamic Awards Graph

By providing the user with individual charts, the prototype enables both the reviewer and the board members with specific information concerning each candidate. But the vision of the VOPS was to aid the user in quickly and efficiently interpreting a

range of promotion factors. With this in mind, the system provides a combined chart (Figure 20) that offers a comparative correlation over a common timeline. With this disparate data collected into one chart, the board members can easily achieve comparative analysis at a glance. As Tufte writes,

> We envision information in order to reason about, communicate, document, and preserve that knowledge – activities nearly always carried out on two-dimensional paper and computer screen. Escaping this flatland and enriching the density of data displays are the essential tasks of information design (Tufte, 1990).

Using this concept of information density, each layer extracts data and translates it into a graphical output on the common timeline. A briefer has the option to choose which graphs he or she wants to display and also has the capability to drill down for more detail by simply clicking on the graphs.

The system also provides tools for the briefer to highlight important aspects of the candidate's career by using the mouse to "draw" on the screen.

The idea of the display capability is to provide the briefer with a set of tools he or she can choose from while preparing the presentation prior to the tank sessions. The precept could dictate common presentation rules but within those boundaries, the briefer has the capability to organize a specialized brief, complete with highlights and optional displays, for each record.

In Figure 20, the top line is an overview of the candidate's sea duty (blue bar) versus shore duty (brown bar). The next layer is the candidate's promotion recommendations drawn from the PSR information which correlates to the performance recommendations, or the "fitrep" overview, displayed on the third tier. Considered individually, the layers convey trend lines over time. Taken together, the board members can easily correlate different aspects of the candidate's record over a common timeline and can more easily make associations to certain data.

The awards data, similar to the data displayed in Figure 19, appears on the fourth level where we've added a color coding system that aids in award type differentiation where the eye can easily follow a vertical line that associates the award with a specific time period.

The final layer shows the duty assignment overview as a baseline where the board can get a common understanding of the unit the candidate was working at in relation to a time dimension. Additionally, the system provides the candidate's billet assignment above the command he or she was assigned to. This information is vital when the board sees the candidate's display because they are able to match the type and duration of a specific billet with corresponding timeframes.

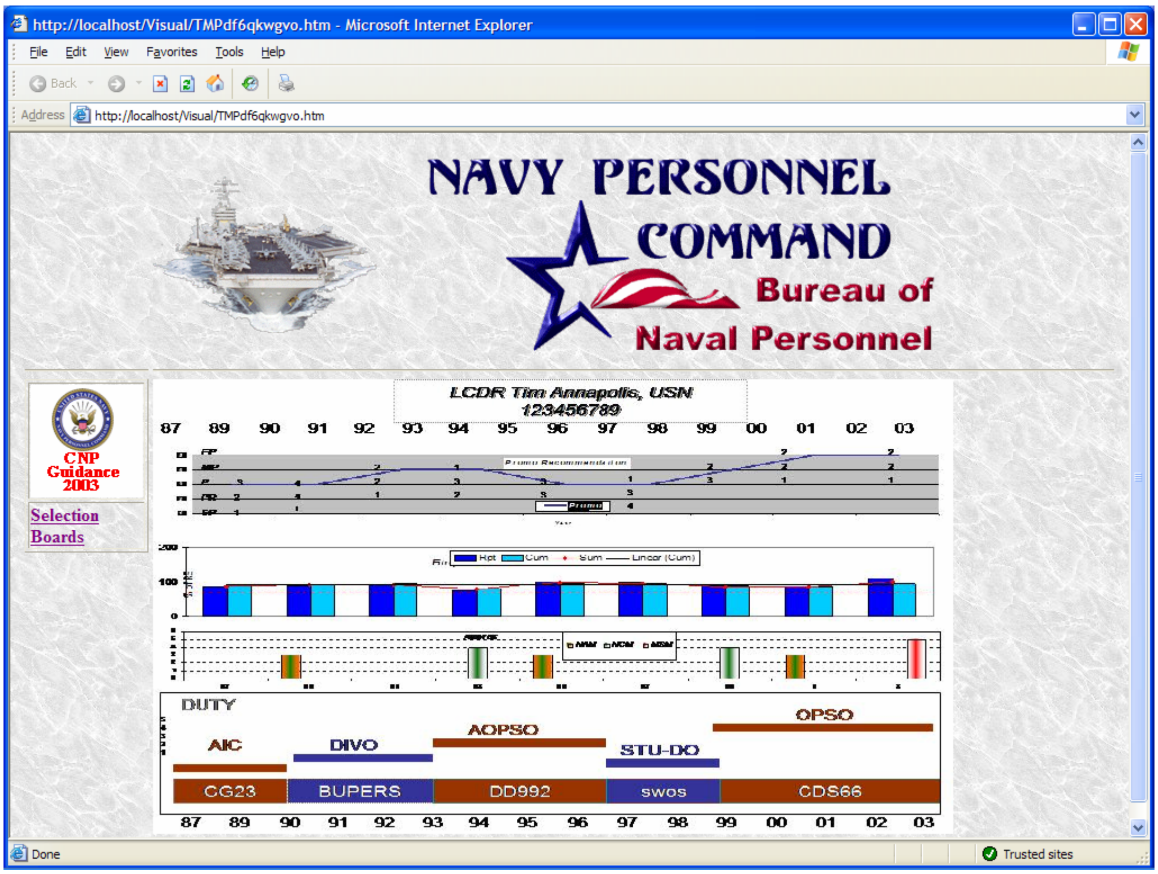


Figure 20. Consolidated Promotion Data Page

In our first iteration of the prototype, we did not provide the duty assignment information. After feedback from the Naval Personnel Command, we discovered a need to further specify not only the unit that the candidate belonged to, but what his or her job title was during the tour. We therefore designed an improved duty layer that showed both the command and duty assignment over the common timeline, as seen at the bottom of Figure 20.

E. SUMMARY

Regardless of the approach eventually adopted, the VOPS prototype can be implemented via an Internet or Intranet solution. By using three-tier architecture, the system provides a maintainable, stable, and robust capability and enables the users to quickly and simply display a large amount of promotion data in a superior interface. The improved presentation takes advantage of proven techniques outlined in chapter III and provides both the briefers and board members with powerful cognitive tools to analyze and compare the different promotion criteria for each candidate. The end result is less mental computation effort required of the board members and a quicker decision cycle. Together, these factors increase the possibility of quality decisions, translating in a better promotion system.

Our ROK analysis has proven that by using a Web-enabled system and graphically displaying the information it would make the process more efficient saving time and money in each board session. In order to answer the first question of whether or not the new process is more effective or more objective we would propose using a side by side analysis where the new system is used in conjunction with the old system in an actual board. We would recommend that this board be a smaller administrative board where the participant board members would have the time and leeway to respond with insights and suggestions. By surveying the board members immediately after the tank session we could gain immediate and helpful insights as to weather or not the graphical displays assist in perceiving and correlating the quantitative information. They could provide invaluable information as to how to improve the test system as well. By surveying multiple boards and making the suggested improvements along the way it would be possible to acquire empirical feedback necessary to determine whether or not the proposed system contributes or detracts from increasing the effectiveness and objectiveness of the overall process. We believe that by reducing the preparation, briefing, and voting times for the briefers', we can ultimately reduce some of the emotional and physical strain internal to multiple decisions in a confined time period. This improvement may well translate to better, more objective, and ultimately more effective and objective decisions.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. INTRODUCTION

This thesis examines the Naval Promotion system and how current board procedures display information to the decision-makers. By examining proven data visualization methods and integrating information technology into the system, we explore the benefits realized by re-designing the procedures that currently require the board members to process raw data into useful information.

This chapter provides the conclusions drawn from the research . It also provides recommendations for further study in the areas of IT implementation and visualization techniques.

B. CONCLUSIONS

The Naval selection board process has embedded procedures that have sufficed for years. By observing their methods, we discovered the possibility to make the working system even better based on modern IT and visualization theories. We concluded that there is no need for a drastic overhaul of the entire system but rather an incremental upgrade incorporated within their current procedures. Specifically, our thesis concludes that a relatively small investment in IT will result in significant returns for many aspects of the existing framework.

1. Effectiveness and Objectiveness of the Selection Board Process

Our primary thesis question asked if a data-information visualization best practices can be embedded in information technology in order to improve the overall effectiveness and objectiveness of the selection board process. Using the Knowledge Value Added (KVA) methodology as a metric, we concluded that significant gains are possible using data-to-information visualization best practices embedded in information technology. Our results show a 126.52 percent increase in ROK. by introducing our recommendations. We can conclude from the increase in ROK that the efficiency of the "to-be" process would be significantly improved from the changes. By using a fully web-enabled system, it would reduce process instructions involved in the sub – processes that take place later stages of the boards overall process which would result in an overall more efficient process. Further, we can surmise that by using our approach, the

execution time in hours would decrease by 120 hours for every 1000 records briefed in the Briefer Review/Annotation phase. Additionally, the "to-be" model showed a reduction of 60 hours per 1000 records in the Brief/Presentation/Vote phase. Further, we believe that by implementing the data visualization techniques introduced in this thesis it would shorten the process instruction involved in the "voting" process even more due to its powerful ability to convert data objects into information so quickly.

Long term effects could include an increase in retention rates due to the enhancement of personnel satisfaction attributed to a more effective determination of the future promotion or assignment of Navy personnel. Unfortunately there is no way of knowing or accurately measuring the validity of this assumption. However, it is reasonable to conclude that by decreasing the strain on the board members and the time it takes to mentally assimilate the data required to make a timely decision that this would ultimately result in an overall increase in the boards effectiveness especially in the later stages of the board when board members are more susceptible to burn out or fatigue.

The design of these displays should strive for uniformity in graphics and assurance that the representation accurately depicts the target numbers. We believe that the objectivity of the current system will be maintained or enhanced by designing the graphical display in such a manner that they accurately portray the information that is given. The ultimate design of the system should keep in mind Tufte's guidance that the representation of numbers, as physically measured on the surface of the graphic itself, should be directly proportional to the numerical quantities represented. Additionally, to gain the most objective results a clear, detailed, and thorough labeling should be used to defeat graphical distortion and ambiguity. Write out explanations of the data on the graphic itself. Label important events in the data.

2. Time Reduction

We concluded that integrating web-based technology with the visualization techniques will reduce the time required to prepare, brief, and make decisions in the promotion process. The current process uses a proprietary display system that simply projects pictures of paper-based records and a crude interface of summary data. By offering a web interface, we conclude that the same data drawn from a database and displayed in graphical forms or organized in a system of hyperlinks will reduce the time

required of all participants. The preparer spends less time correlating the data for the board members which shortens his or her brief. More importantly, the system enables the board members to make quicker decisions based on information more easily ingested.

3. Appropriate Technologies

Web-based data visualization technologies can serve as an enabler to this problem but the question remains of what are the relevant criteria for deciding which technologies are the most appropriate.

Based on our research and experience with this problem, we conclude that a three-tier architecture is most appropriate. The robust nature and the current maturity of the architecture lends itself to storing, processing, and presenting information needed for the promotion boards. Using this layered approach, technology advances can be adopted in each layer thus providing expandability to the system without requiring complete dependency on current technology maturity in the entire system.

4. User Interface Design

What is an appropriate user interface design for this decision problem? We believe that a web-based interface provides a clear, concise, familiar interface for the modern board member. Using graphs generated by the data, the board members can quickly assimilate the data and make a decision. As the members become accustomed to the format, time required to locate pertinent data decreases. By using the interface most prevalent in personal and professional computer interaction, we take advantage of a built-in skill set to the computer-savvy members. Even for those less computer-savvy, the interfaces are intuitive and the graphs adhere to the proven theories set forth by Tufte, thus benefiting all the board members regardless of their technical background.

C. RECOMMENDATIONS FOR FURTHER STUDY

1. Implementation of the Theoretical Study

Within the next year is an optimal timeframe to carry forward the research outlined in this thesis. The Military Personnel Command, in conjunction with the Space and Naval Warfare Systems Information Technology Center (SITC), developed the Single Integrated Human Resources Strategy (SIHRS). The goal of this strategy is to support the Defense Integrated Military Human Resources System (DIMHRS). DIMHRS is the Joint program, also initiated from the 1996 Defense Science Board, which will

unify human resource support for both active duty and reserve members of all four of the armed services (Feldmann, 2003). Additionally, at this time Naval Personnel Command is implementing a technical up-grade on the EMPRS system and the goal is that it will all be Web-based in the near future. We recommend collaborative involvement with NPC to incorporate our theoretical solution into the evolving upgrades. This thesis provides academic support based on proven visualization methods therefore the next logical step is to move forward with NPC for the implementation phase. Important factors to take into account are the following:

- compatible with EMPRS
- compliant within the NMCI network standards
- compatible with PeopleSoft HRMS applications

2. Five-Vector Model Incorporation

Eventually a system such as this could be incorporated to display the Five Vector Model where individuals would be evaluated for promotion and advancement throughout their career as outlined by the vector model. The Five Vector Model aligns professional development requirements with certifications and qualifications both military and civilian that are recognized as the industry standard. Once the fleet has identified the requirements, subject matter experts in each field of expertise plot them on the vector model where an individual should ideally meet those milestones in their career. The model also considers personal development, leadership and management, and individual performance. By using the measures of performance in the Five Vector Model, it may eventually be possible to eliminate the correlation of OSR/PSR data in the promotion process entirely.

Implementing our design using the model as a baseline template is more of a radical redesign but something that PERS-8 has a definite interest in. We recommend having one vector on one screen (five vectors for the five screens). Using this methodology, the board would not even have to use the OSR/PSR data but rather gather the information they need based on the combination of visualization techniques outlined in this thesis and the Five Vector Model. Furthermore, by directly extracting the data for the Five Vector Model from Naval Personnel Database or NSIPS (Navy Standard

Integrated Personnel System which will replace 4 legacy systems used in the Fleet), a single source solution will be possible.

3. Other Services

The ideas and prototype we developed for this thesis are portable to the other services. Minor personalization for each branch would be necessary but implementing the system could improve all the board operating procedures. We recommend research into the other services' promotion processes and an evaluation of each to determine how this thesis could improve each process. We feel that such an evaluation would reveal tremendous possibilities to improve any and all promotion boards.

4. Virtual Board

The most radical recommendation we have is a study to determine if a virtual board could eventually occur. Due to the rapidly advancing technologies of collaborative tools and database utilities, combined with high bandwidth and reliable, secure connections, we feel that the Navy could save a large amount of funds by conducting boards in a disbursed, collaborative manner.

Our vision is to have board members log on via secure accounts and perform their record evaluations online. The centralized hub could take care of the administration and logistics but massive savings could be realized by not requiring board members to travel to a common site for the proceedings. Whether the board would resemble a Video Teleconference (VTC) or a prerecorded presentation of each record brief are some of the issues we recommend for further study.

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